PHYTOPLANKTON COMPOSITION AND ABUNDANCE IN LAKE ONTARIO DURING IFYGL

E. F. Stoermer, M. M. Bowman, J. C. Kingston
and A. L. Schaedel

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ABSTRACT

Based on samples collected during the International Field Year for the Great Lakes, the phytoplankton assemblage of Lake Ontario is dominated by taxa indicative of degraded water quality, including many potentially nuisance producing species. Many taxa characteristic of the offshore waters of the upper Great Lakes are either absent from the flora or very rare. Compared to the upper lakes, the flora of Lake Ontario undergoes extreme seasonal succession, with diatoms predominating during the winter and early spring, green algae becoming abundant during the summer, and blue-green algae showing a distinct fall peak. Various species of microflagellates are a relatively important element of the flora during all seasons. Succession during the spring bloom appears to be controlled by the thermal bar, and our data suggest control by depletion of essential nutrients following stratification. Striking differences were apparent in samples collected on comparable dates in the spring of two successive years. These differences apparently result from exceptional weather conditions which prevailed during the first sampling period. The distribution of species particularly tolerant of disturbance appeared to be controlled by both proximity to major population centers and lake morphometry. The abundance of halophilic species in most productive areas suggests effects of conservative ion contamination as well as nutrient enrichment.

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CONCLUSIONS AND RECOMMENDATIONS

1. The phytoplankton flora of Lake Ontario is qualitatively and quantitatively dissimilar from all but the most severely impacted regions of the upper Great Lakes.

   It would appear appropriate to develop separate predictive models for the lower (Erie and Ontario) and upper (Huron, Michigan and Superior) Great Lakes.

2. Our data suggest that there are considerable yearly differences in the abundance and composition of the phytoplankton assemblage in Lake Ontario, apparently related to weather conditions during the spring phytoplankton maximum.

   Data from IFYGL biology and chemistry projects should be interpreted with caution, especially as a basis for projections. Any further projects of this type should be designed to provide a multi-year data base.

3. Local effects of major population concentrations are evident in both the composition and abundance of the phytoplankton flora, however integrated, lake-wide effects appear to be strongly controlled by morphometry.

   Predictive models should account for morphometric effects.

4. Although this project does not provide direct evidence, patterns of phytoplankton abundance and succession in Lake Ontario are consistent with the hypothesis that phosphorus is the primary nutrient controlling productivity in the system.

   It appears that limitation of phosphorus loadings is an appropriate first management strategy.

5. The phytoplankton flora of most productive regions of Lake Ontario is dominated by halophilic species.

   Greater emphasis should be placed on reduction of conservative element contamination, as well as nutrient limitation.

6. Lack of a sufficient historic data base restricts interpretation of present results in the context of long-term trends within the Lake Ontario system, except by analogy to better studied comparable systems.

Effort should be made to develop such comparative data, either by recovery and analysis of historic samples or by paleolimnologic methods.

7. The phytoplankton assemblage of Lake Ontario appears to be highly unstable, on both a seasonal and yearly basis.

   It is suggested that, due to this unstable food base, fisheries management practices successful in the upper Great Lakes may prove less productive if adopted in Lake Ontario.

(Conclusions regarding particular taxa and general conditions in Lake Ontario are discussed in more detail in summary section beginning on p. 363 following.)

INTRODUCTION

This project was initiated as part of an integrated series of investigations of Lake Ontario under the general aegis of the International Field Year for the Great Lakes. The Field Year was conceived primarily as an attempt to construct a precise model of the hydrological characteristics of Lake Ontario. Since it was early recognized that the unique bank of physical data generated would have great utility in constructing a more general process model of the Lake Ontario ecosystem, the original concept was modified to include biological and chemical measurements appropriate to the construction of the more general model. The general plan has been published (IFYGL 1972) and need not be discussed here. It is important to keep in mind, however, that the biological and chemical sampling effort was carried out largely within the constraints of the original project concept. It will be apparent also that the original plan underwent evolutionary changes during the course of the project, some of which were imposed by operational constraints in sampling platform availability and operational capabilities. Of perhaps greater importance were modifications of the original sampling plan in response to the effects of a major meteorological "accident." June 1972 was one of the coldest and wettest Junes on record in the Lake Ontario basin. Near the end of this extremely atypical month, significant portions of the region were subjected to the fringe effects of Tropical Storm Agnes (Atmospheric Environment Service 1972) which resulted in record rainfalls at many stations within the Lake Ontario drainage basin. Since early results of several projects indicated significant effects of these events, the originally conceived sampling plan was considerably extended to provide comparison between the spring sampling periods in two successive years.

One of the primary objectives of the project was to obtain quasi-synoptic coverage of the entire lake during successive time intervals representing periods of characteristic seasonal succession of biological populations within the lake. Some emphasis was placed on the early spring period, which has the highest seasonal standing crop of primary producer organisms in most temperate lakes.

The 60 primary stations sampled are shown in Figure 1. During May 1972, sampling of these stations was only about 50% effective due to weather-induced operational restrictions on the sampling platform utilized. Sampling during 1973 was on a somewhat more restricted basis. Nominally 40 of the 60 original stations were chosen, but operational problems associated with severe winter weather resulted in the omission of a limited number of stations on certain cruises.

In all cases arbitrarily specified depths were sampled. Depths selected were 1, 5, 10, 15, 20, 25, 30, 40, 50, 100, 150 and 200 m. In cases where depth at the station sampled did not permit a full 12-bottle cast, sampling profile was truncated to the nearest specified depth and an additional sample was taken about 5 m above bottom. Depths sampled are indicated in summary plots of vertical profile information following.

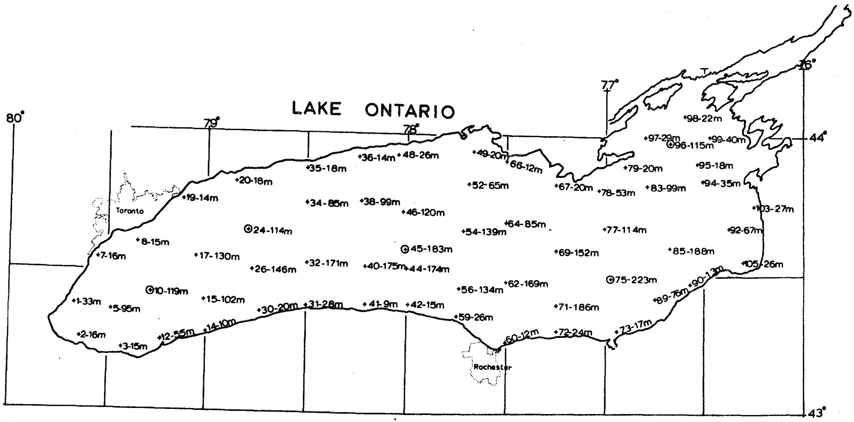


FIG. 1. Primary station locations; master stations circled.

Acquisition and interpretation of phytoplankton population information suitable for use in a project of this size presents certain problems which have never been completely solved. Perhaps the most serious difficulty is that identifications are not possible by other than manual methods. This means that analysis of samples, under the best of conditions, proceeds quite slowly and is subject to human errors which are difficult to control. The problem is compounded in the present instance by the fact that the phytoplankton of the Laurentian Great Lakes is rather poorly known, and standard references covering the taxonomic groups of greatest interest are not avialable. It is thus necessary, to a substantial degree, to treat with some rather fundamental taxonomic problems during the course of such an investigation. Because of the strong seasonal succession of phytoplankton communities, unique problems arise during each successive sampling during a year's period. This entire problem is further compounded by the diversity of groups present and their basic biochemical differences. Because of these differences, no single preservation technique is completely suitable for all organisms which may be encountered in any sample. There are many organisms present in the phytoplankton of Lake Ontario which can only be identified with any degree of confidence in the living condition. When treating with the number of samples generated by the IFYGL project, it is exceedingly difficult to treat every sample with all methods necessary to assure the best treatment of every taxonomic group which could conceivably be present in a given sample. This is especially true in the case of organisms which are best identified in the brief time they remain viable after collection. As a practical matter it is usually necessary to make some compromise between the amount of data coverage, in terms of samples taken, and data quality, in terms of complete and confident identifications.

In this project we placed primary emphasis on development of information regarding the abundance and distribution of particular populations. Because of the necessity to process samples rapidly into a form where they could be stored for considerable periods of time before final analysis, we chose to prepare these samples as semi-permanent microscope slides.

In order to extend the sample coverage, we also made a rapid automated analysis of particles present in the waters sampled according to size class. While this measurement does not allow the identification of particular populations or even, necessarily, the segregation of phytoplankton from other classes of particles occurring in the water, we felt that comparison of trends in such measurements with population information and gross biomass estimates developed by other projects might serve to extend the usefulness of both types of observations.

Because of the current unsatisfactory state of taxonomic treatments of Lake Ontario phytoplankton, we felt it highly desirable that one of the outputs of IFYGL should be a coherent set of reference samples from the lake which might serve as the basis for revisionary work on certain groups by specialists. Such archival samples are also highly desirable

as a means of checking results of the project and to provide a means of extending observations should this become desirable. Such reference samples also, in a sense, serve to provide a standard against which future changes in the Lake Ontario ecosystem may be judged.

In this project we also collected and analyzed a limited number of chlorophyll samples from IFYGL biology-chemistry master stations. This effort was partially motivated by the desire to be able to compare these values, which were fluorometrically determined, with spectrometrically determined values from these stations by other projects. These samples were also used to inspect correlations between this measure of standing crop and the particle count and population counts generated by this project in its initial phases, before the more extensive set of spectrometrically determined chlorophyll values developed by other projects was available.

Summarization of the information developed by this project presents some problems. Since the information is to be included in further efforts to develop a model of the Lake Ontario ecosystem, it is necessary to include the original semi-reduced data in an easily available format. This material is too extensive to be conveniently reproduced in the standard report format. In the interests of economy and to reduce errors of transcription, we have submitted the semi-reduced digital information on magnetic tape to the project officer together with one complete hard-copy printout. Printout format for the species count information is shown in Table 1 and for the particle count information in Table 2. A summary listing of labels for archival samples has been provided to the project officer, and an example of the label information is given in Table 3.

Graphic summaries of this information are presented in the results section following. The summaries include representations of abundance of particles by size class for the seasons sampled, of total phytoplankton abundance, the abundance of most common major taxonomic divisions, and the distribution of some of the more important or interesting species and genera.

TABLE 1. Format for phytoplankton species information.

Lake Ontario (IFYGL), Station 96-All Depths

year:	1973	Julian day:	80 (21 Mar)
station:	96	depth:	10.0 m
latitude:	43° 58.8'	longitude:	76° 40.8'
number of cells counted:	1258	volume of water scanned:	0.477 ml
diversity:	2.404	evenness:	0.688

division	number of species	cells/ml	SE	CV	% pop.
Cyanophyta (blue-green algae) . .	1	12.6	8.4	0.67	0.477
Chlorophyta (green algae)	4	127.8	10.5	0.08	4.849
Bacillariophyta (diatoms)	22	2308.0	276.5	0.12	87.599
Chrysophyta (chrysophytes). . . .	1	33.5	33.5	1.00	1.272
Cryptophyta (cryptomonads). . . .	1	14.7	10.5	0.71	0.556
Pyrrophyta (dinoflagellates). . .	2	31.4	2.1	0.07	1.192
other	0	0.0	0.0	****	0.0
undetermined.	2	106.8	77.5	0.73	4.054
total	33	2634.7	397.9	0.15	100.000

species name	cells/ml	SE	CV	% pop.
Stephanodiscus subtilis	670.2	41.9	0.06	25.437
Asterionella formosa.	580.1	23.0	0.04	22.019
Stephanodiscus minutus.	261.8	10.5	0.04	9.936
Stephanodiscus tenuis	245.0	27.2	0.11	9.300
Stephanodiscus hantzschii	209.4	58.6	0.28	7.949
Melosira islandica.	100.5	46.1	0.46	3.816
Ulothrix sp. #1	85.9	14.7	0.17	3.259
Undetermined flagellate sp. #1.	81.7	81.7	1.00	3.100
Stephanodiscus alpinus.	44.0	2.1	0.05	1.669
Tabellaria fenestrata	37.7	16.8	0.44	1.431
Diatoma tenue var. elongatum.	35.6	23.0	0.65	1.351
Synura uvella	33.5	33.5	1.00	1.272
Stephanodiscus binderanus	29.3	8.4	0.29	1.113
Scenedesmus bicellularis.	27.2	6.3	0.23	1.033
Undetermined flagellate sp. #2.	25.1	4.2	0.17	0.954
Peridinium sp. #1	25.1	4.2	0.17	0.954
Surirella angusta	23.0	2.1	0.09	0.874
Nitzschia bacata.	16.8	4.2	0.25	0.636
Cryptomonas sp. #1.	14.7	10.5	0.71	0.556
Nitzschia dissipata	14.7	6.3	0.43	0.556
Oscillatoria limnetica.	12.6	8.4	0.67	0.477
Ankistrodesmus sp. #1	8.4	4.2	0.50	0.318
Fragilaria crotonensis.	8.4	8.4	1.00	0.318
Nitzschia sp. #2.	8.4	0.0	0.0	0.318
Cymbella turgida var. pseudogracilis.	6.3	2.1	0.33	0.238
Dinoflagellate sp. #1	6.3	6.3	1.00	0.238
Phacotus sp. #1	6.3	2.1	0.33	0.238
Navicula menisculus var. upsaliensis.	4.2	0.0	0.0	0.159
Nitzschia filiformis.	4.2	4.2	1.00	0.159
Achnanthes clevei	2.1	2.1	1.00	0.079
Amphora ovalis.	2.1	2.1	1.00	0.079
Navicula tripunctata.	2.1	2.1	1.00	0.079
Rhoicosphenia curvata	2.1	2.1	1.00	0.079

TABLE 2. Format for particle count information.

LAKE ONTARIO PARTICLE COUNTS
(PARTICLES/100 ML)

CRUISE 7 JUNE 12 - JUNE 16, 1972

STA #	DEP (M)	PARTICLE SIZES (IN MICRONS) 5-10	10-20	20-40	40-80	80-150
1	1	97247	23044	2053	98	8
1	5	104374	25281	1895	82	3
1	10	95736	23978	2249	135	14
1	15	97873	27320	2387	123	7
1	20	50819	19292	1194	36	7
1	25	44788	14890	780	40	3
1	30	52286	11752	530	60	10
2	1	98525	23623	3593	144	11
2	5	116173	24859	2646	172	10
2	10	117907	19870	1655	228	21
3	1	115860	24860	2122	225	23
3	5	115772	27945	2718	201	17
3	10	114153	25469	2431	169	12
3	12	87514	23868	2229	187	13
5	1	95381	38328	5031	193	10
5	5	84475	33454	4846	382	35
5	10	75784	24686	2985	147	10

TABLE 3. Example of label for archival samples.

IFYGL Lake Ontario
500 ml raw water sample thru GFC
filt. preserv. 6H20: 3 ETOH: 1 HCHO
Dr. Eugene Stoermer, U. of Mich.
DATE: 1 NOV 72 STATION: 52
SAMPLE NO.: 1869 DEPTH: 1 m

MATERIALS AND METHODS

All samples were collected by Niskin Bottle cast using a multiple bottle rosette sampler. In all cases discrete splits of the initial 5-liter samples were taken by ship technical personnel and delivered to project personnel for further processing. Preservation and processing of samples were initiated immediately, and all samples were preserved within 1/2 hr of collection. The only exceptions were discrete, small-volume samples retained for immediate observation of living phytoplankton, which were discarded without further processing after observations were completed.

PARTICLE COUNT SAMPLES

Samples for particle count analysis were taken in 125 ml polypropylene bottles pre-spiked with sufficient commercial formalin to give final concentration of approximately 1%. Early in the project some problems were experienced with polymerization of the small volumes of formalin used after prolonged storage, but this was corrected by reducing storage time of spiked bottles to less than 10 days. After collection and preservation, samples were returned to the laboratory without further treatment.

Samples were analyzed by passing 100 ml volumes through a HIAC optical occlusion particle counter fitted with a 5-150 μm counting head. Samples were gently and uniformly agitated before analysis to assure uniform suspension of particles. Results of single, initial runs are reported since it was discovered that results of multiple runs showed a reduction in readings in larger size channels and an increase in smaller size channels, apparently resulting from mechanical disruption of the larger phytoplankton colonies and detrital aggregates. In all cases the machine was adjusted to read in channels with nominal size of 5-10, 10-20, 20-40, 40-80, and 80-150 μm, according to manufacturer's specifications.

Complete records of particle count results have been submitted to the project officer on magnetic tape. Summary plots of this information are given in the results section following.

PHYTOPLANKTON POPULATION ANALYSIS

Samples for phytoplankton population analysis were taken as a 150 ml split of the original 5-liter Niskin Bottle cast. These subsamples were immediately fixed with glutaraldehyde (4% by volume) and stored in the dark at approximately 4°C for at least 4 hr and not longer than 8 hr to assure complete fixation. After fixation, sample bottles were gently agitated to assure resuspension of phytoplankton present and a 50 ml volume was withdrawn for further processing.

Material was concentrated by filtration onto 25 mm "AA" Millipore filters, partially dehydrated through an ethanol series and embedded in beechwood creosote. Prepared filters were mounted on 50 x 75 mm glass slides and covered with a 43 x 50 mm #1 cover glass. Preparations were allowed to dry for approximately two weeks, during which time embedding medium lost by volatilization was periodically replaced, then the edges of the cover glasses were sealed with paraffin.

Material was analyzed by visual counts of phytoplankton cells present using Leitz Ortholux microscopes fitted with fluorite oil immersion objectives giving approximately 1250X magnification and nominal Numerical Aperture of 1.32. Population estimates given are the average of two 10-mm radial strips counted, corrected for volume. Effective filtration diameter in the filtration apparatus used is 20 mm.

Raw counts were encoded in computer compatible format on punched cards. Subsequent data sorting and manipulation were computerized. Hard-copy data summaries in the format shown in Table 1 are available for all samples counted. Summaries include estimates of absolute frequency, relative frequency, and error associated with these quantities. Assemblage parameters calculated include estimates of diversity and evenness as well as total assemblage abundance and the contribution of the several major Divisions.

Summary information in the results section following is machine-plotted from reduced data stored on magnetic tape. Intermediate programs are utilized to compile and call data of particular interest for plotting routines or for further processing.

ARCHIVAL PLANKTON COLLECTIONS

Archival samples were taken as 500-ml subsamples of the original 5-liter Niskin Bottle cast. Subsamples were immediately filtered onto 47-mm Watten "GFC" glass fiber filters, placed in 5-dram amber glass capsule vials, and preserved in a mixture of 6 parts water of collection, 3 parts 95% ethanol, and 1 part commercial formalin. Vials were then sealed and temporarily labeled for return to the laboratory. In the laboratory, vials were inspected and additional preservative added if needed, and then permanently labeled with computer-generated labels of the type shown in Table 3. Finally vial caps were sealed with paraffin to assure against loss of preservative.

REFERENCE CHLOROPHYLL SAMPLES

Samples for chlorophyll analysis were taken as 250-ml splits of original 5-l Niskin Bottle casts at IFYGL master stations only. Subsamples were immediately filtered onto 47-mm diameter HA Millipore filters and placed in 5-dram amber glass capsule vials containing 10 ml of 90% acetone, labeled and stored in the dark at approximately 0°C.

Samples were analyzed after return to the laboratory and usual storage/extraction times were on the order of 6 days. After return to the laboratory, extracted samples were analyzed for chlorophyll *a* and phaeopigments fluorometrically according to the methods of Strickland and Parsons (1968).

RESULTS

CHLOROPHYLL VALUES AT MASTER STATIONS

The vertical distribution of chlorophyll *a* values in mg/m^3 corrected for phaeopigments at the master stations sampled in Lake Ontario is given in Figure 2. In May, mid-lake stations 24 and 75 showed relatively low and uniform values throughout the water column. At station 96, however, values were extremely high (17 mg/m^3 at 1 and 5 m) in the near-surface water and significantly higher than the other stations at other depths. In June, values were somewhat elevated at station 10, and a much larger surface peak was present at station 24. Stations 45 and 75, which both fell within the "cold core" region during this sampling cruise, had very low and vertically uniform chlorophyll *a* values. Samples from station 96 taken during this cruise were unfortunately lost due to a laboratory accident. In July, all master stations in the open lake showed remarkably similar chlorophyll levels and patterns of vertical stratification. Peak values occurred at 10 m depth in all of them, and significant decreases in chlorophyll concentration were noted both above and below this depth. At station 96, in the eastern end of the lake, values were lower at all depths and fairly uniform down to 10 m. There was a very slight peak at 10 m, and values declined below that depth, as they did at the other stations. Corrected chlorophyll *a* values were surprisingly low in August, particularly at stations 24 and 75. Stations 10 and 45 showed slight peaks at 5 m depth, and values at station 96 were also elevated and more uniform with depth.

In October, very low values were present at station 10. Stations 24 and 45 had somewhat higher values and concentrations were fairly uniform down to 100 m. Surface values at station 75 were similar to those found at the previous two stations, but declined below 20 m and became very low below 30 m. Chlorophyll values at station 96 were comparable to the other stations sampled at the surface and remained at the same levels at all depths sampled. In November, no pronounced vertical trends were evident at the stations sampled and values were quite low, except at station 96 in the eastern end of the lake. In February, chlorophyll values were low and uniform at the open-lake stations sampled. No samples from station 96 were obtained during this cruise. In March, values remained low and relatively uniform at the open-lake stations, but were significantly elevated at station 96, in the eastern end of the lake. In April, values increased but remained relatively constant with depth at the four open-lake stations. Values remained significantly higher, and evidence of vertical stratification was present at station 96. In June, chlorophyll values increased significantly in the upper part of the water column, with peak values occurring within the top 10 m at most of the stations. Station 45 presented a somewhat anomolous case, with peak values occurring at 30 m.

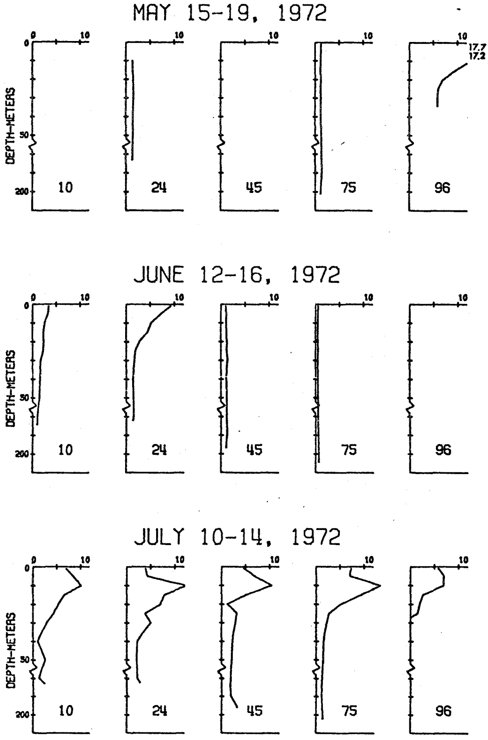


FIG. 2. Vertical distribution of chlorophyll *a* at master stations.

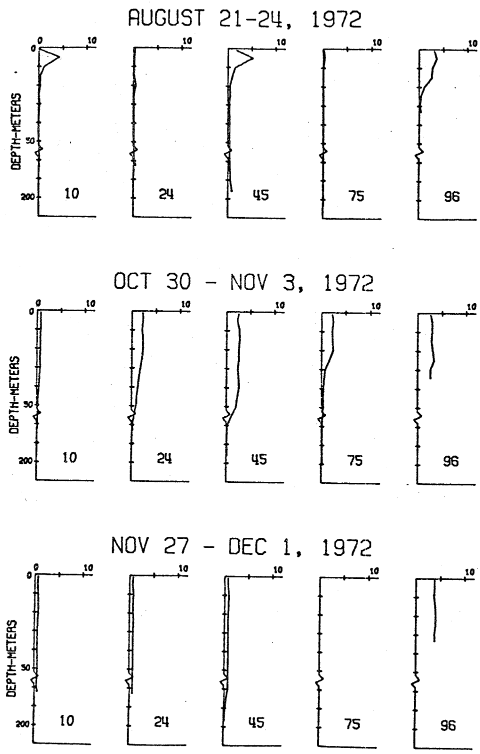


FIG. 2 continued.

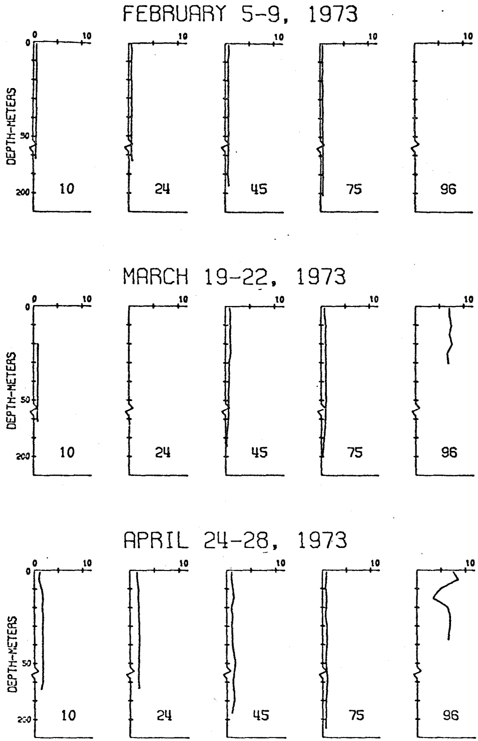


FIG. 2 continued.

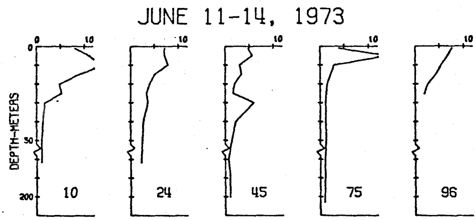


FIG. 2 continued.

PARTICLE COUNT DATA

Graphic representations of the areal distribution of particles in the particular size classes measured in the near-surface waters of Lake Ontario are given in Figures 3-7. Representations of verticle distribution of particles in the same size classes sampled on each of the biology-chemistry cruises are given in Figures 8-10.

For the purposes of this project, particle count data are regarded as relatively crude information, but sufficiently accurate to allow reasonable interpretation of trends between points measured by more accurate but more tedious methods. Since there are obviously particles other than living algae in the seston of Lake Ontario, it cannot be expected that the particle count technique would give an acceptably accurate estimation of the abundance of phytoplankton on a direct basis. Since particle count size classes are directly related to the volume of particular particles sensed by the device, it might be suspected that a closer relationship would be found between particle counts as an estimate of phytoplankton abundance and a measure of gross biomass, such as chlorophyll, than to direct counts of phytoplankton, which contain species of vastly different physical sizes and states of aggregation. This supposition appears to be supported by the results of our study. When compared with fluorometrically determined chlorophyll values from the master stations (Table 4), reasonably close correlations were found, particularly with the intermediate size classes, in samples from the first two cruises. Although remaining significant statistically, correlation declined during the summer months and tended to increase in the fall. No correlation was found in samples taken during February, but they increased again during the early spring sampling period. Correlations for samples and cruises on comparable dates were not as

TABLE 4. Correlations between fluorometrically determined chlorophyll *a* values and particle counts for all depths at master stations.

Month	P.C. Channel						
	5-10	10-20	20-40	40-80	80-150	5-150	R@.99
May	.8670	.9467	.9390	.8042	-.0318	.9285	.5256
June	.8684	.7806	.2885	.3640	.8092	.8342	.3843
June*	.9114	.9297	.8697	.8584	.8130	.9366	.3887
July	.7893	.8638	.6996	.4977	.3749	.8279	.3575
August	.5994	.7006	.6806	.6505	.5145	.6386	.3477
October	.6940	.7328	.6863	.5586	.4259	.7134	.3575
November	.8317	.9298	.9206	.8704	.3779	.8835	.3932
February	.0067	-.3476	-.1164	-.1122	-.2211	-.0695	.3801
March	.7434	.9222	.9621	.8872	.1206	.8294	.4182
April	.3159	.5943	.7294	.2793	.0178	.4930	.3477
April**	.3305	.7533	.8843	.6357	.1796	.5514	.3509
June	.5647	.7262	.7964	.8708	.7549	.6471	.3646
June***	.5952	.8599	.8060	.8753	.7557	.6986	.3683

* Excluding 1 extreme outlier point apparently resulting from sediment contamination of P.C. sample (station 75, near-bottom sample, 221 m).

** Excluding 1 extreme outlier point apparently resulting from contamination of P.C. sample (station 45, 150 m sample).

*** Excluding outlier point apparently resulting from P.C. bottle contamination (station 75, 1 m sample).

strong as they had been the previous year.

Correlations are strongly affected by the introduction of single nonrepresentative samples into the set considered. In the results presented (Table 4), we have recalculated certain values excluding data from samples which were obviously contaminated with sediment. While certain other data points, particularly in the set from the October cruise, are regarded as suspicious, we have included all cases where source of contamination could not be determined beyond reasonable doubt by inspection of the sample. It is apparent that correlation could be improved significantly by the adoption of arbitrary criteria for exclusion of outliers.

The anomolous results obtained from the February samples are somewhat confounding. The most immediately plausible explanation would be a systematic error in the chlorophyll results from this month. We have

not been successful in detecting any such error. We suspect that the unsatisfactory result may arise from the fact that very low values for particle counts and chlorophyll were present in samples from this cruise and many of the algal populations present were in the larger size class, resulting in relatively poor extraction of the chlorophyll present by the method utilized. This factor also may produce a reduction in observed correlations during the summer months when assemblages at most stations were dominated by the larger green and blue-green algae.

Comparison of the particle count data with spectrometrically determined chlorophyll values furnished by other projects is somewhat less encouraging (Table 5). Although highly significant statistically except during February, the correlations between results from the two methods are not what might be expected from methods which purport to measure the same quantity. Correlations are particularly poor in results from the summer cruises, and no correlation was found in the previously noted anomolous February case. Glooschenko et al. (1972) have noted particularly high phaeopigment fractions in Lake Ontario waters during the summer months. Although corrected chlorophyll *a* data were used in both data sets discussed here, part of the apparent non-correspondence between the two methods may result from inconsistencies in arriving at accurate correction for phaeopigments. The correlations between raw cell counts of phytoplankton and spectrometrically determined chlorophyll values are also very poor for the summer cruises. A relatively high correlation was found between raw cell counts and spectrometrically determined chlorophyll *a* values in February, although correlations with other parameters measured were extremely low.

Areal Distribution by Size Class

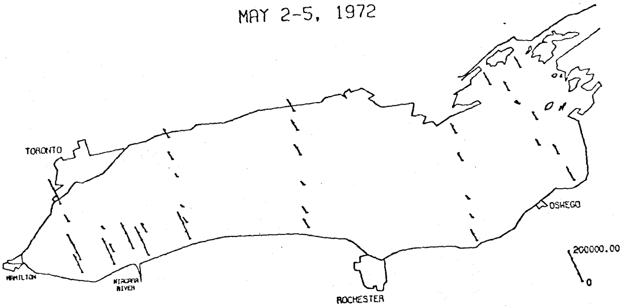
Data on the distribution of particles in the surface waters of Lake Ontario are presented in Figures 3-7. In addition to data gathered as part of the principal project, we have included measurements made under the auspices of a complementary project (Intensive Study of Lake-Wide Changes in Spring Phytoplankton and Certain Related Parameters, supported by U.S. Department of Commerce NG-17-72) in the interests of tracing the time course of early spring changes with the greatest fidelity. Cruises undertaken as part of the principal project are designated as Main-Lake Biology-Chemistry (BC) and those undertaken as part of the other project are designated as Spring Bloom (SB) cruises.

Samples taken on the first SB cruise showed relatively high densities of 5-10 μm particles at stations in the Niagara and Toronto vicinities. Over the rest of the lake, densities were moderate at most stations, with pronounced low at several mid-lake stations and slightly elevated at stations nearest shore (Fig. 3A). Samples taken on the second SB cruise showed slightly reduced densities of particles in this size class at stations near Niagara and Toronto, but increased levels at stations nearest shore in the rest of the lake, particularly along the southern shore (Fig. 3B). Although the stations near Niagara and

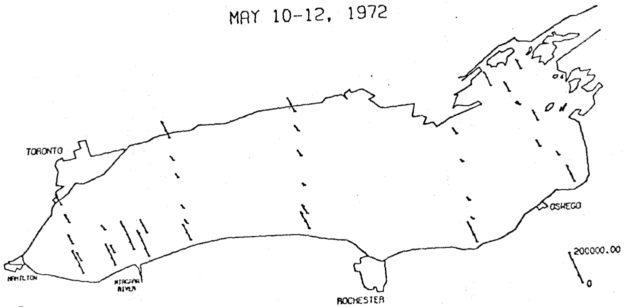
TABLE 5. Correlation coefficients for EPA spectrometrically determined chlorophyll *a* values and: (1) fluorometrically determined chlorophyll *a* values (master stations only), (2) 10-20 μm particle counts, (3) 20-40 μm particle counts, (4) total cell counts.

	May	June	July	Aug.	Oct.	Nov.	Feb.	March	April	June
(1)	.8890	.9765	.8500	.6949	.8930	missing	.0206	.9027	.9643	.7103
(2)	.7171	.5782	.7177	.6194	.4724	missing	.2930	.6474	.5410	.3863
(3)	.5856	.4536	.6094	.5291	.4703	missing	.0195	.6610	.3941	.3335
(4)	.6277	.5213	.3573	-.1409	.1644	missing	.7740	.8628	.8837	.2835

Toronto were not sampled on the first BC cruise, samples taken at this time showed continued increase in particle densities at nearshore stations along the southern shore (Fig. 3C). Results from the third SB cruise indicated that this trend continued, with increases beginning at offshore stations in the southeastern part of the lake (Fig. 3D). A continued spread of relatively high particle densities in the 5-10 μm size class was evident in the results from the fourth (Fig. 3E) and fifth (Fig. 3F) SB cruises, particularly at stations in the eastern and western ends of the lake. By the time of the June 1972 BC cruise, relatively high and uniform particle counts were found at all stations sampled, except for a group of offshore stations in the southern half of the lake (Fig. 3G). A similar situation was found on the sixth (Fig. 3H) and seventh (Fig. 3I) SB cruises, when particle densities were relatively high and uniform except at station 45 which showed strikingly low values at both sampling periods. Particle densities in this size range were fairly uniform in samples taken during July (Fig. 3J) and August (Fig. 3K), although somewhat reduced values were found at stations in the Hamilton-Niagara vicinity during July and the Oswego vicinity during August. Stations sampled during the October BC cruise showed markedly reduced and rather irregular 5-10 μm particle densities (Fig. 3L). By the time of the November 1972 BC cruise, particle densities were greatly reduced at all deep-water stations, but remained high or tended to increase at stations near shore and in the shallow northeastern basin (Fig. 3M). Approximately the same situation was evident during February 1973 (Fig. 3N), although slightly increased particle densities were noted at a few offshore stations. In March (Fig. 3 O), particle densities remained high at stations nearest the southern shore but were consistently reduced at stations near the north shore. The same trend was visible during the April cruise (Fig. 3P), with a general reduction in average particle count values. Similar to the previous year, by June 1973 particle count values had become relatively uniform across the lake (Fig. 3Q) except for a couple of strikingly low values at offshore stations and a pronounced high at



A



B

FIG. 3. Areal distribution of 5-10 μm particles.

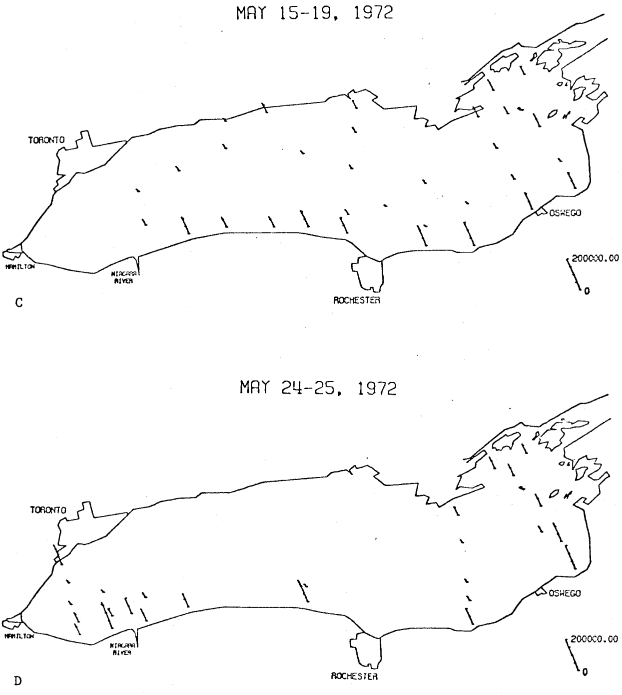
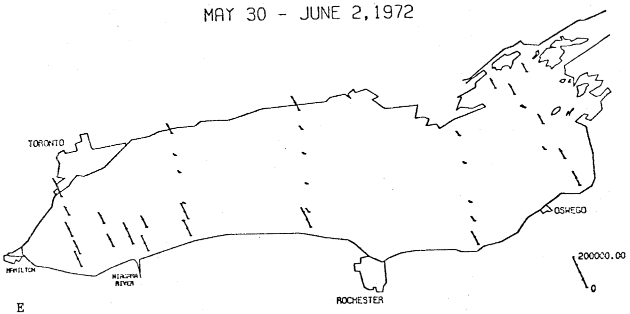
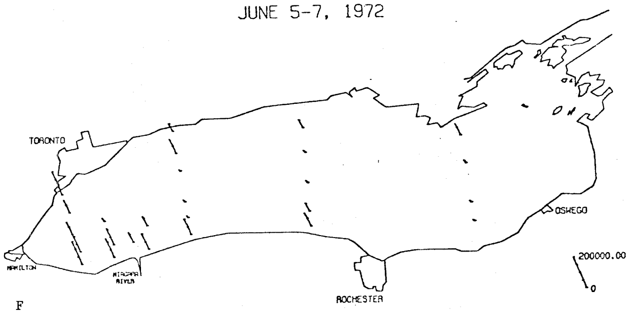


FIG. 3 continued.

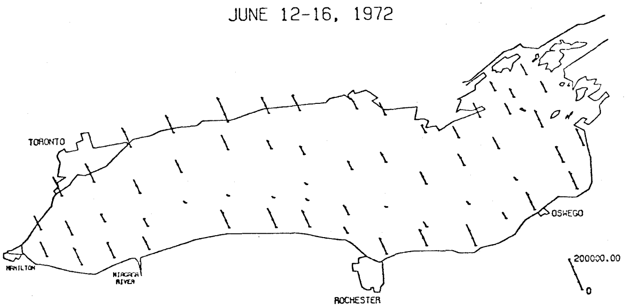


E

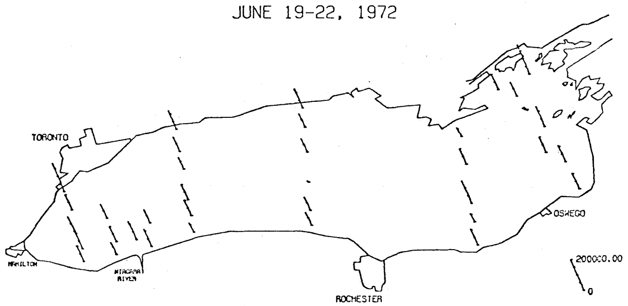


F

FIG. 3 continued.



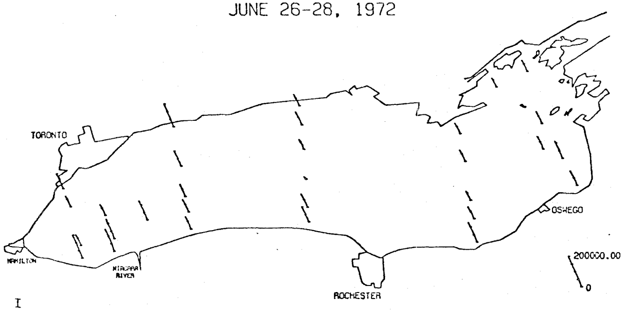
G



H

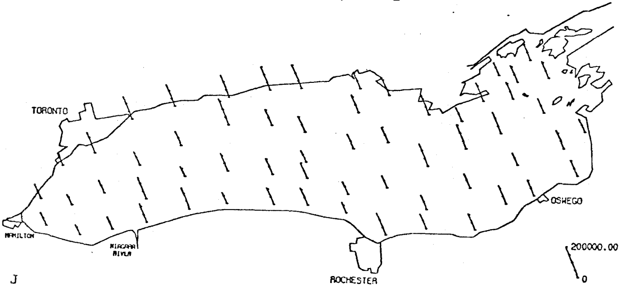
FIG. 3 continued.

JUNE 26-28, 1972



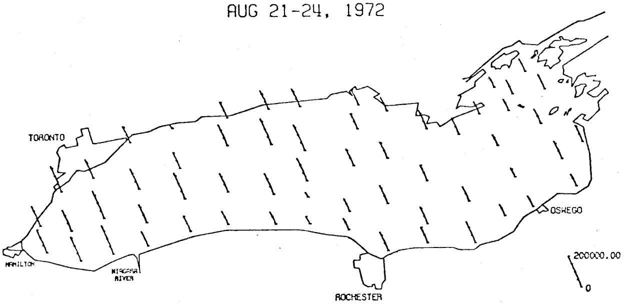
I

JULY 10-14, 1972

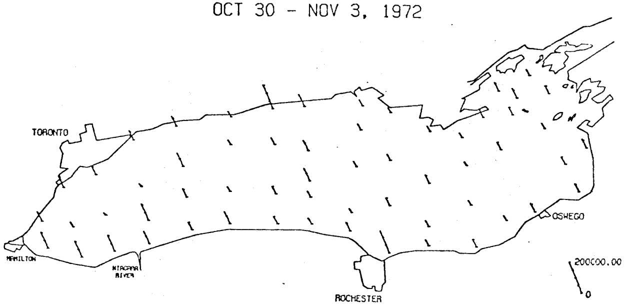


J

FIG. 3 continued.



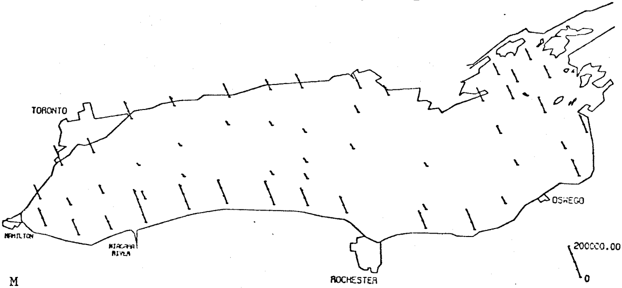
K



L

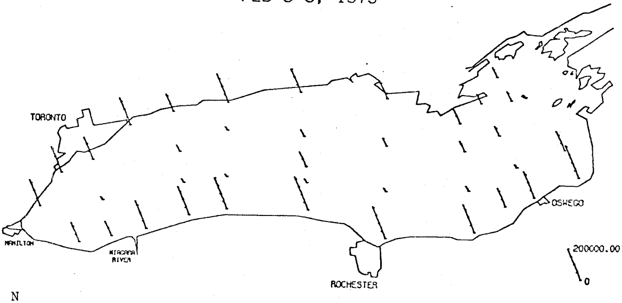
FIG. 3 continued.

NOV 27 - DEC 1, 1972



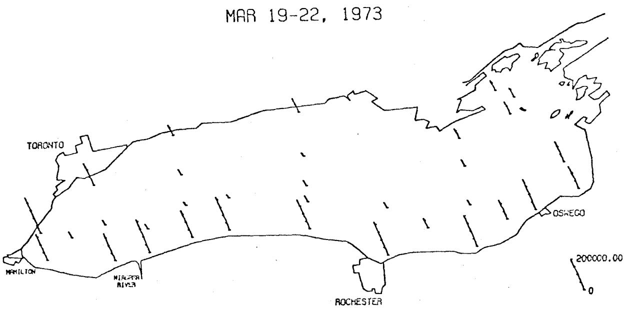
M

FEB 5-9, 1973

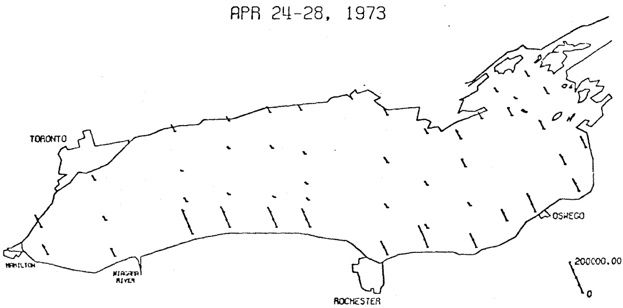


N

FIG. 3 continued.

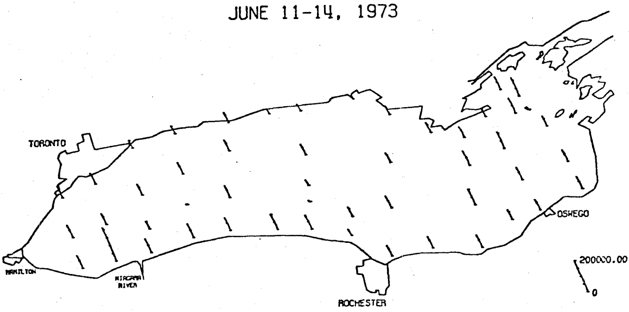


O



P

FIG. 3 continued.



Q

FIG. 3 continued.

station 12 near Niagara.

Samples from the first SB cruise (Fig. 4A) showed relatively high densities of 10-20 µm particles at stations near Niagara and Toronto and at certain stations in the far eastern part of the lake. Over the rest of the lake there was a trend toward higher counts at stations nearer shore, but values were appreciably less than in the Niagara area. A similar situation was found on the second SB cruise (Fig. 4B), although counts at stations nearest shore in the main lake had increased appreciably. Samples from the first BC cruise (Fig. 4C) showed decreased levels of 10-20 µm particles at nearshore stations along the north shore, but levels remained high along the southern shore, particularly in the Mexico Bay region and in the northeastern basin. Average values decreased somewhat in samples from the third SB cruise (Fig. 4D) and remained relatively stable in samples from the fourth SB cruise (Fig. 4E) although relatively high values had begun to spread to offshore stations. This trend continued, on the basis of results from the fifth SB cruise (Fig. 4F), and by the time samples from the June BC cruise were taken (Fig. 4G) significantly low values were found only at a group of stations offshore in the southern half of the lake. The area of the lake having water with low particle densities apparently continued to decrease, since such values were noted only at three stations sampled during the sixth SB cruise (Fig. 4H) and at a single station sampled during the final SB cruise in late June (Fig. 4I). In

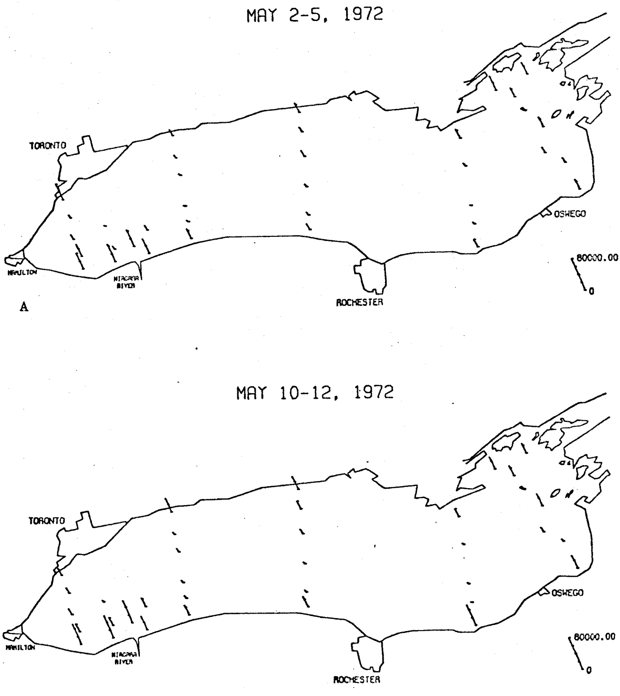
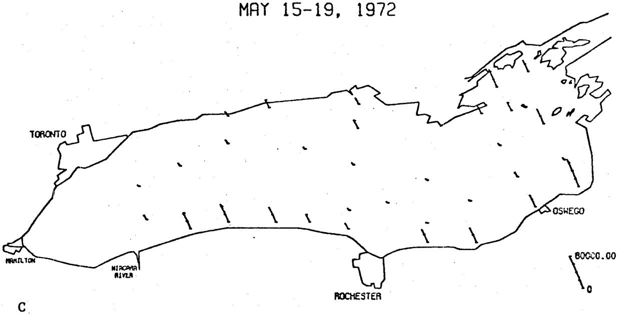


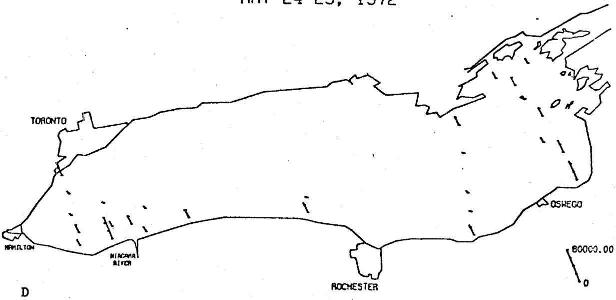
FIG. 4. Areal distribution of 10-20 μm particles.

MAY 15-19, 1972



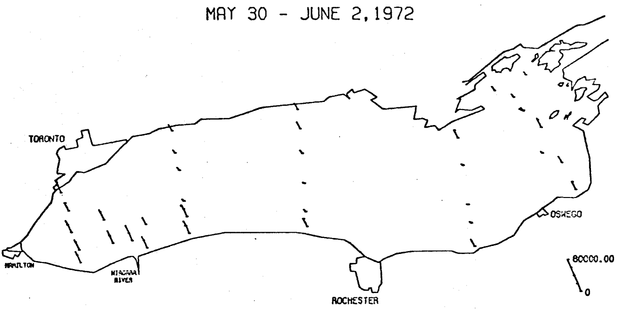
C

MAY 24-25, 1972

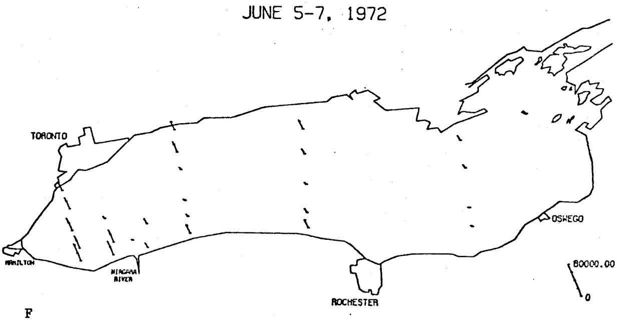


D

FIG. 4 continued.

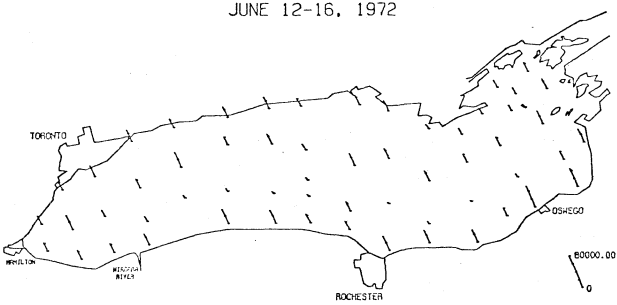


E

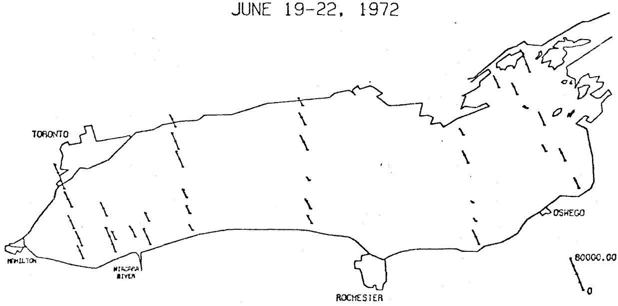


F

FIG. 4 continued.



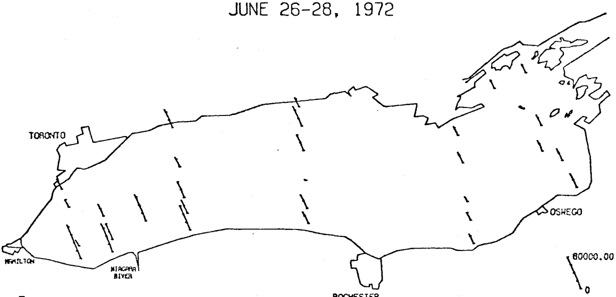
G



H

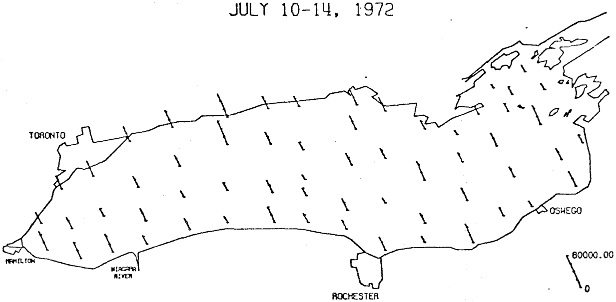
FIG. 4 continued.

JUNE 26-28, 1972



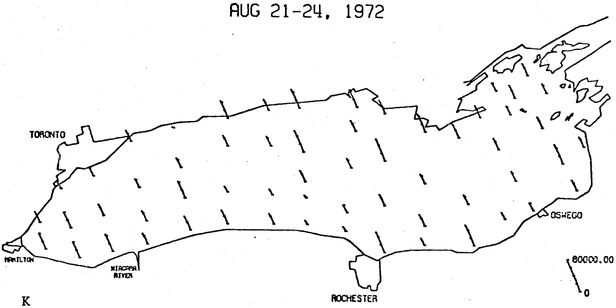
I

JULY 10-14, 1972

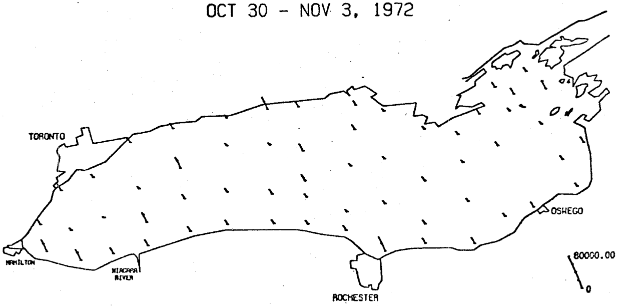


J

FIG. 4 continued.



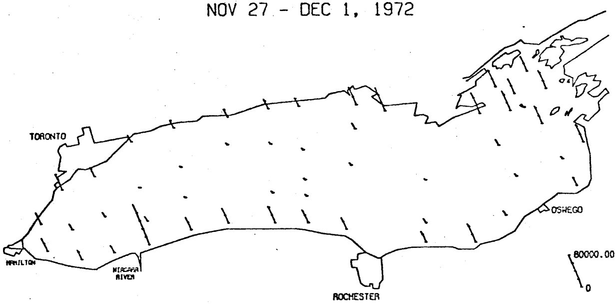
K



L

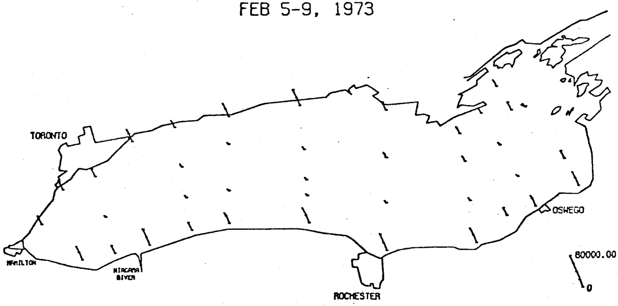
FIG. 4 continued.

NOV 27 - DEC 1, 1972



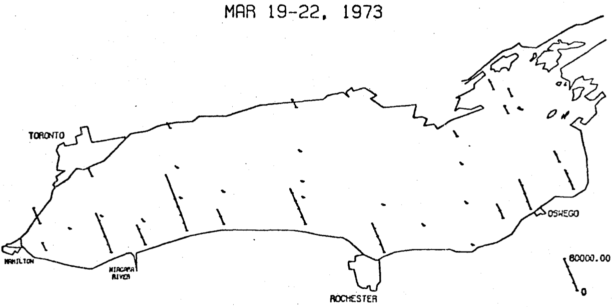
M

FEB 5-9, 1973

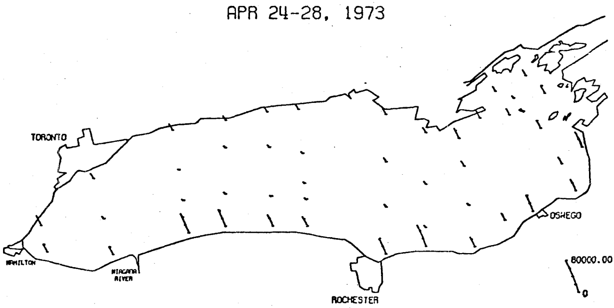


N

FIG. 4 continued.

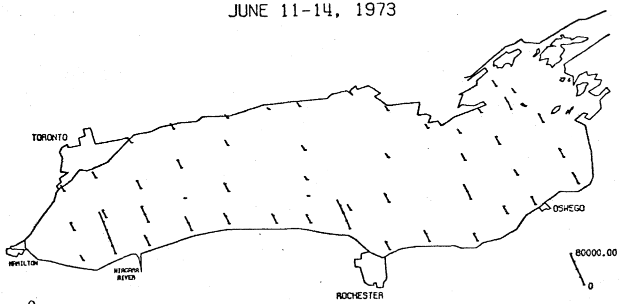


O



P

FIG. 4 continued.



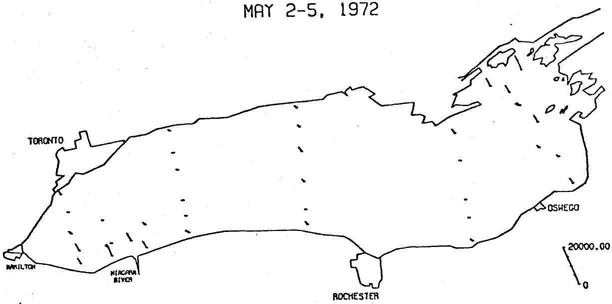
Q

FIG. 4 continued.

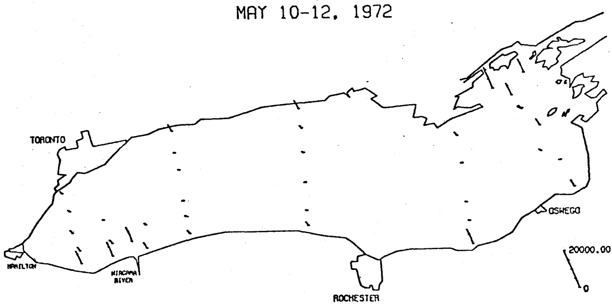
July (Fig. 4J), 10–20 μm particle densities were relatively high and uniform at most stations sampled throughout the lake, although there was some tendency towards reduction in abundance at stations in the eastern basin and near shore, which had highest values early in the season. Particle count values in this channel remained relatively high and uniform at all stations sampled during the August cruise (Fig. 4K), although some minor but apparently systematic variations were present. Average values were significantly lower in samples from the October cruise (Fig. 4L) and quite irregular over the lake, although there was some tendency for higher values at stations nearest shore. The latter trend apparently continued, since samples from the November cruise (Fig. 4M) showed significantly higher counts at stations nearest shore and in the far northeastern basin than in the open lake. Counts at nearshore stations decreased somewhat in our February 1973 samples (Fig. 4N), but substantial increases were noted at most stations along the southern shore in March (Fig. 4 O). Values at these stations decreased somewhat in April (Fig. 4P) but tended to increase slightly at offshore stations and along the northern shore. By June (Fig. 4Q), relatively high levels were found at most stations across the lake, but there appeared to be a definite south-to-north trend in abundance with highest values being found at nearshore stations in the Rochester and Niagara vicinities.

Relatively low levels of 20-40 μm particles were found at stations sampled during the first SB cruise in early May (Fig. 5A). Highest levels were noted at stations in the southwestern part of the lake, near Niagara, and in the northeastern island area. Approximately the same situation was evident in samples collected during the second SB cruise (Fig. 5B), but appreciably increased levels were found at stations nearest shore. Samples from the May BC cruise (Fig. 5C) showed considerably increased levels at nearshore stations in the southern part of the lake and in the northeastern island area, but not at stations along the north shore. Maximum values noted on the previous cruise had declined somewhat by the time samples were taken on the third SB cruise (Fig. 5D) but remained relatively high in the eastern part of the lake. This pattern was changed by the time samples were taken on the fourth SB cruise (Fig. 5E), and highest values were found at stations near Niagara. A similar situation was found on the basis of samples from the fifth SB cruise (Fig. 5F), although there was some tendency for higher values to spread to stations farther from shore. By the time of the June BC cruise (Fig. 5G), highest values were found at a band of stations in the north half of the lake and at stations along the southern shore, with low values along the north shore and at offshore stations in the southern half of the lake. On the sixth SB cruise (Fig. 5H), lowest values were found in the south central part of the lake, with relatively higher densities in the north and east and particularly in the west end of the lake. Samples from the final SB cruise (Fig. 5I) showed highest values in the southwestern part of the lake and an apparent west-east overall trend. In July (Fig. 5J), average values were reduced and densities more variable between stations, as they were in smaller size ranges. In August, average values increased somewhat (Fig. 5K) but there was considerable variation between stations and no outstanding regional patterns. In October (Fig. 5L), particle densities in this size class were reduced to low and rather uniform levels, but increased at stations in the northeastern island area, and to a lesser extent at nearshore stations throughout the lake (Fig. 5M) during November. In February (Fig. 5N), values were uniformly low except for a marked high at station 14, near Niagara. Our March samples showed increased values at certain stations along the southern shore (Fig. 5 O), and by April (Fig. 5P) this trend had spread to all nearshore stations and to stations in the northeastern part of the lake. Rather irregular values were found in samples from the June 1973 cruise (Fig. 5Q), but there appeared to be a north-south trend in abundance, as there was in the smaller size ranges.

Samples from the first SB cruise (Fig. 6A) showed relatively high counts of particles in the 40-80 μm channel at stations in the northeast and southwest parts of the lake and at some stations in the north-central region. Results from the second SB cruise showed a slight increase at stations nearest shore on both sides of the lake (Fig. 6B). Conditions were apparently similar during the time the samples from the May BC cruise were taken (Fig. 6C), with relatively high values at most shallow stations. Results from the third SB cruise (Fig. 6D) indicated a slight decline, except at stations in the east and west ends of the

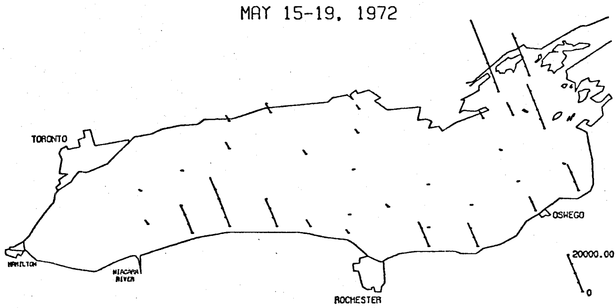


A

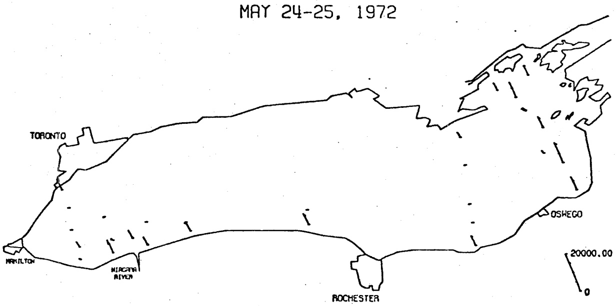


B

FIG. 5. Areal distribution of 20-40 μm particles.



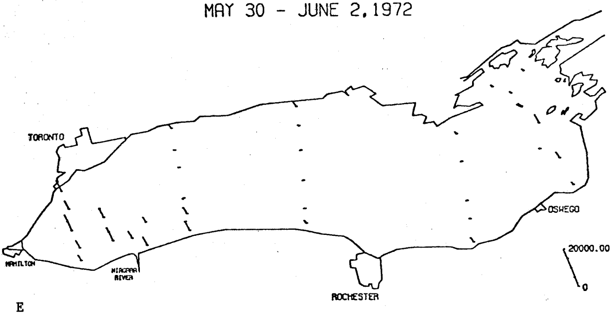
C



D

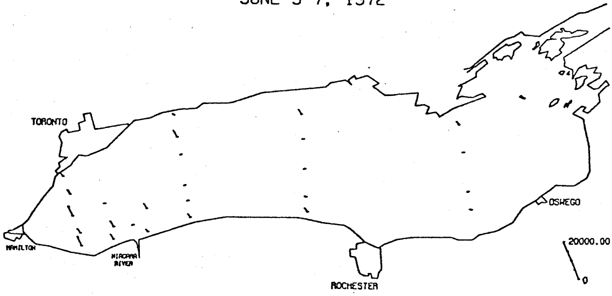
FIG. 5 continued.

MAY 30 - JUNE 2, 1972



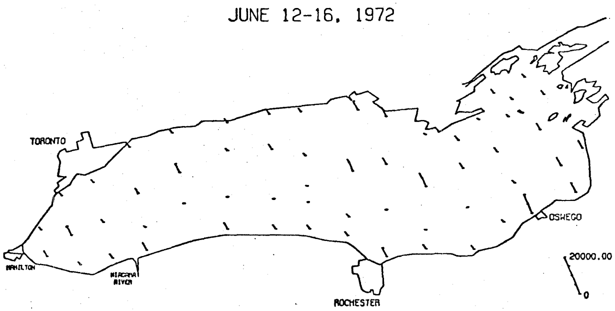
E

JUNE 5-7, 1972

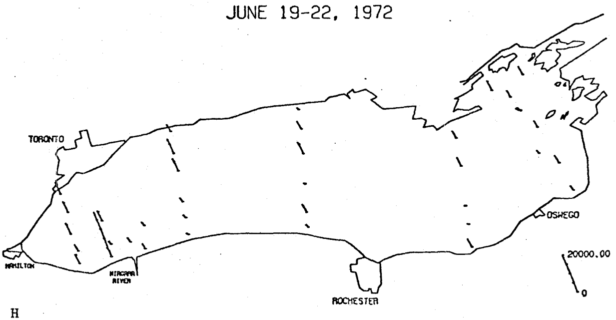


F

FIG. 5 continued.

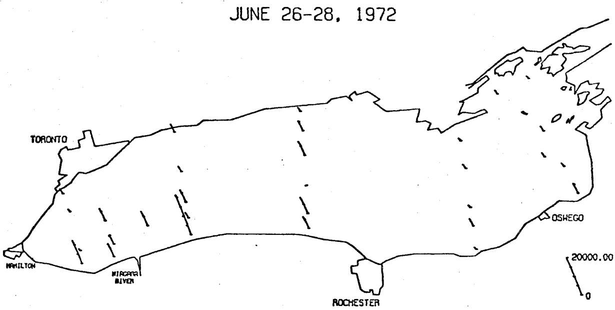


G

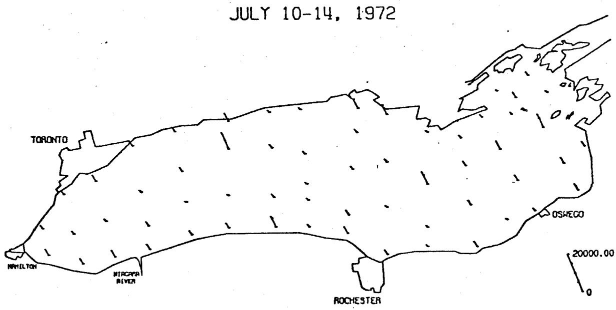


H

FIG. 5 continued.



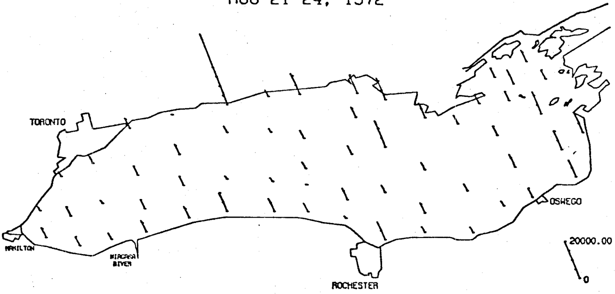
I



J

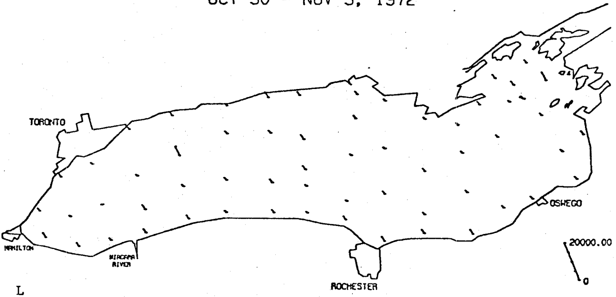
FIG. 5 continued.

AUG 21-24, 1972



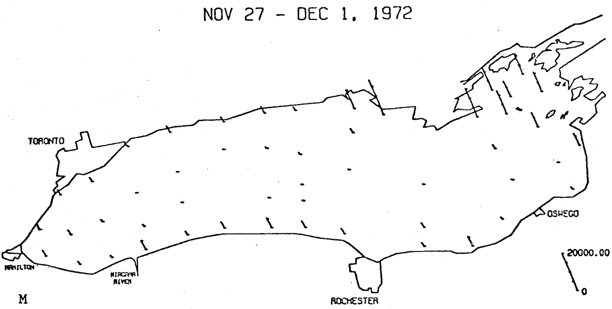
K

OCT 30 - NOV 3, 1972

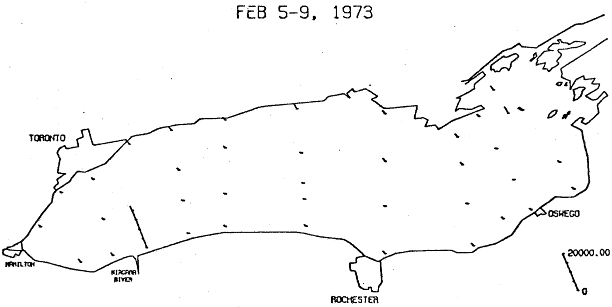


L

FIG. 5 continued.



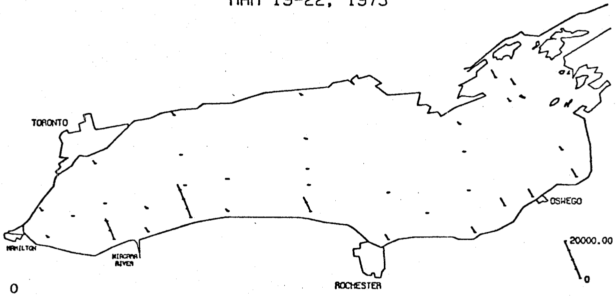
M



N

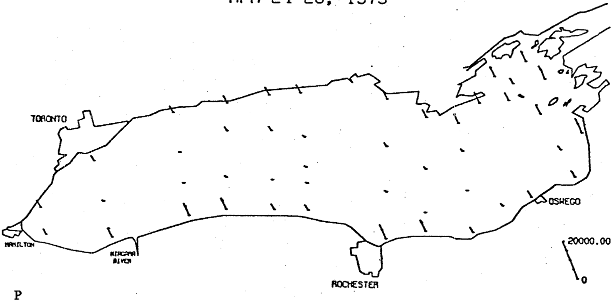
FIG. 5 continued.

MAR 19-22, 1973



O

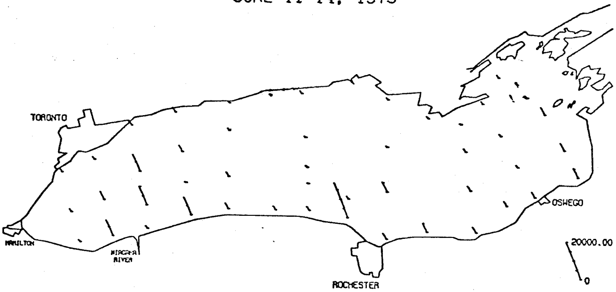
APR 24-28, 1973



P

FIG. 5 continued.

JUNE 11-14, 1973



Q

FIG. 5 continued.

lake, and the trend toward higher levels at these stations was evident in the results from the fourth SB cruise (Fig. 6E). Levels remained relatively high in the west end of the lake at the time of the fifth SB cruise (Fig. 6F), and increases were noted at some offshore stations. The same pattern evident in counts from the 20-40 μm channel appeared to be present in results from the June BC cruise (Fig. 6G), with relatively high values along the south shore and in the north central part of the lake, and low counts along the north shore and in the south central region. Relatively low counts were present at some offshore stations and a group of stations east of Niagara during the sixth SB sampling period (Fig. 6H), with relatively high counts at stations immediately west of Niagara. During the final SB cruise (Fig. 6I) there appeared to be a southwest to northeast trend in values, as there had been in some of the smaller channels. Samples from the July BC cruise (Fig. 6J) showed relatively high and uniform values except for low values at a group of stations in the south central part of the lake and a few stations near Toronto. Values increased appreciably at most stations sampled during August (Fig. 6K), but declined again in October (Fig. 6L). In November (Fig. 6M), low values were found at most offshore stations but were uniformly higher at stations nearest shore and considerably higher at stations in the northeastern sector of the lake. Only isolated high counts with no particular pattern were found during February 1972 (Fig. 6N) and March 1973 (Fig. 6 0). In April

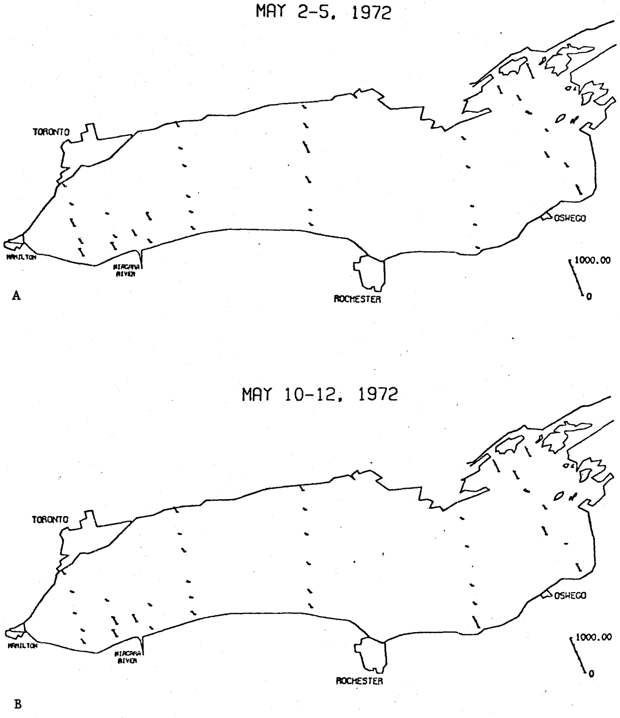
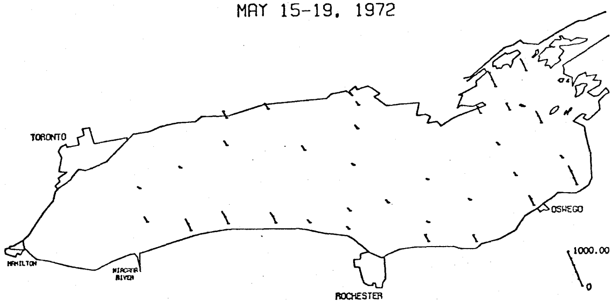
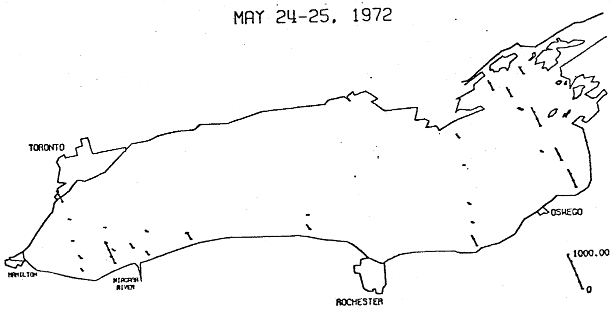


FIG. 6. Areal distribution of 40-80 μm particles.



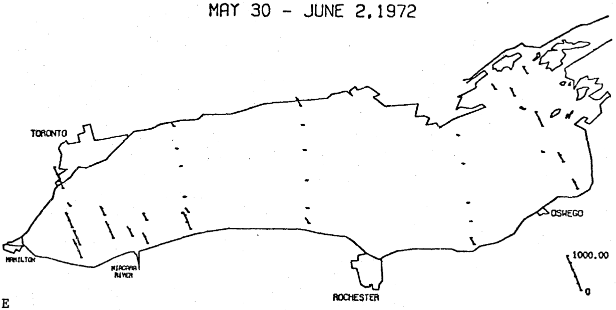
C



D

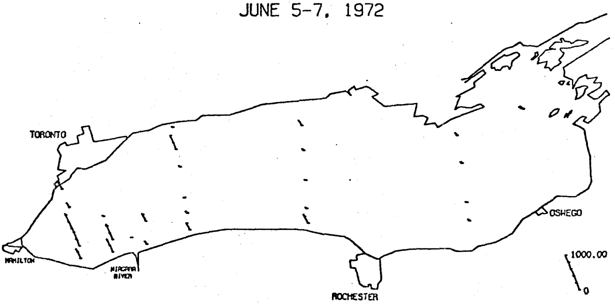
FIG. 6 continued.

MAY 30 - JUNE 2,1972



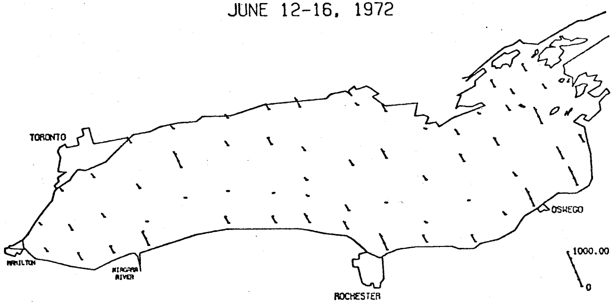
E

JUNE 5-7, 1972

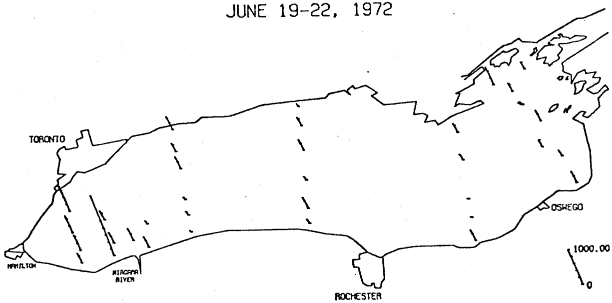


F

FIG. 6 continued.



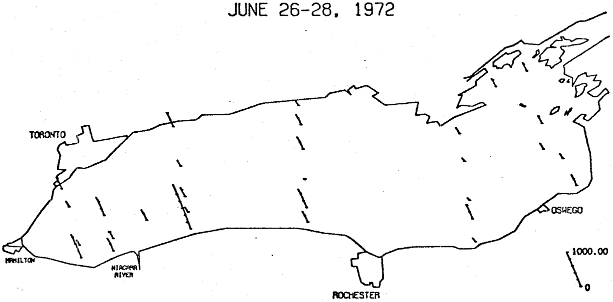
G



H

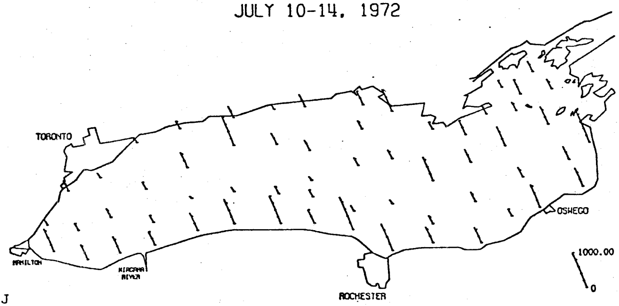
FIG. 6 continued.

JUNE 26-28, 1972



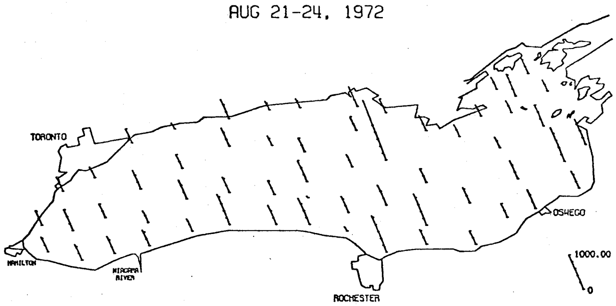
I

JULY 10-14, 1972

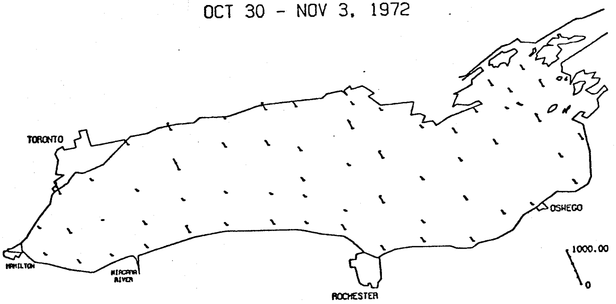


J

FIG. 6 continued.



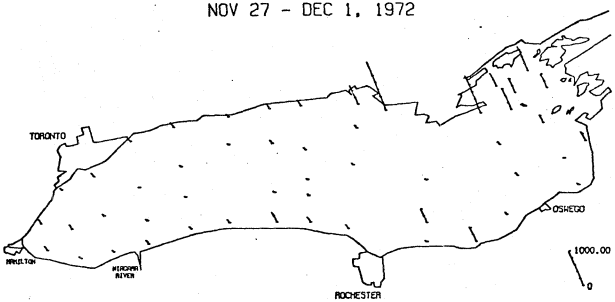
K



L

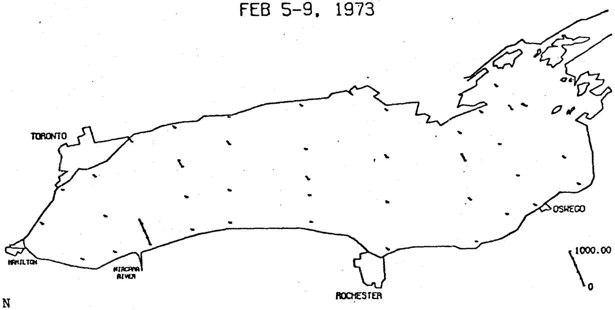
FIG. 6 continued.

NOV 27 - DEC 1, 1972



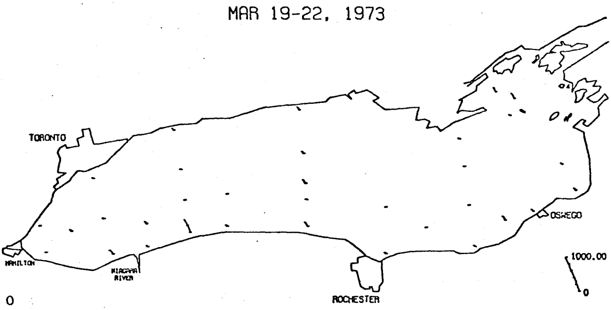
M

FEB 5-9, 1973

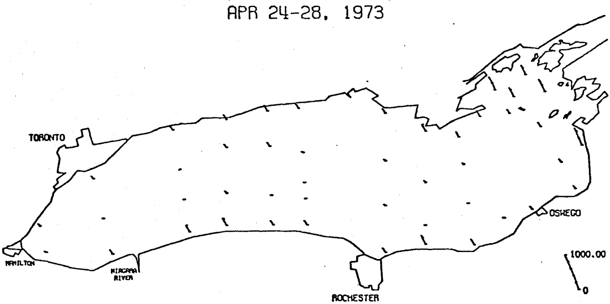


N

FIG. 6 continued.

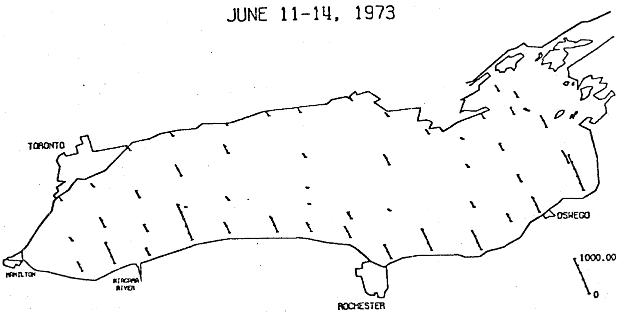


O



P

FIG. 6 continued.



Q

FIG. 6 continued.

(Fig. 6P), however, there was a definite pattern of higher occurrences at stations nearest shore and in the eastern island area. In June (Fig. 6Q), highest values were found along the southern shore and in the north central part of the lake, as was the case in some of the smaller channels.

Particle counts in the 80-150 μm size channel were relatively low in samples from the first two SB cruises (Fig. 7A,B), and only slight increases were noted at stations near shore and in the eastern part of the lake during the May BC cruise (Fig. 7C). Continued slight increases were noted at stations in the eastern part of the lake and stations near Niagara on the three following SB cruises (Fig. 7D, E, F). Samples from the June BC cruise showed scattered very high values at stations along the southern shore and in the eastern part of the lake (Fig. 7G). Samples from the two following SB cruises (Fig. 7H, I) showed a tendency towards decrease at stations in the eastern part of the lake and increase at stations in the west. In July (Fig. 7J), however, values in this size range were very high at stations along the southern and eastern shores and relatively low at stations in the western part of the lake. By August, overall average values had declined (Fig. 7K) and striking declines were evident at stations that had been high the previous month. High values were present at a series of stations in the

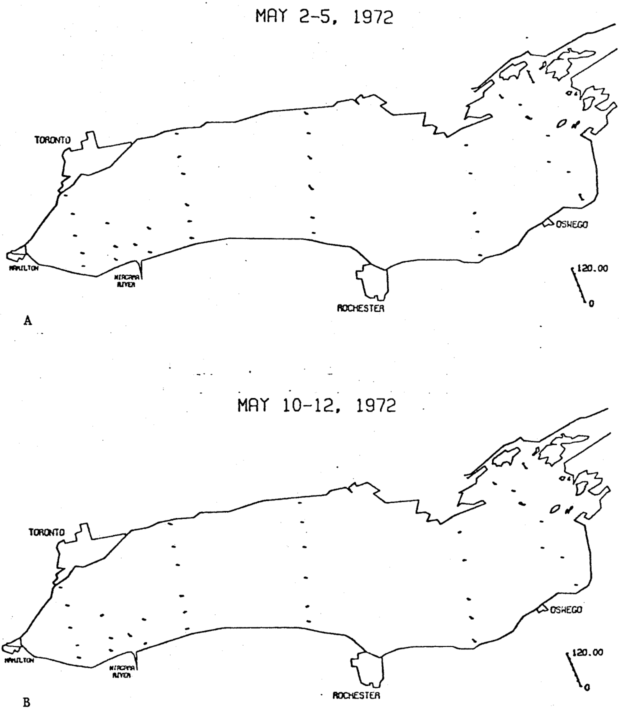
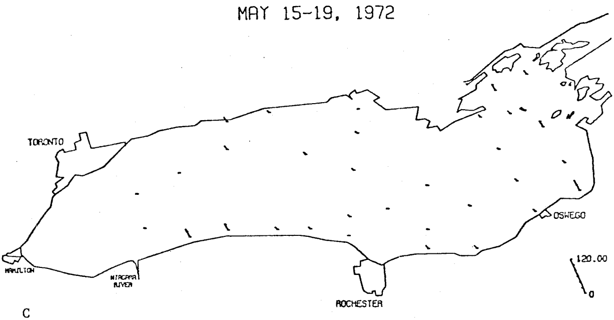
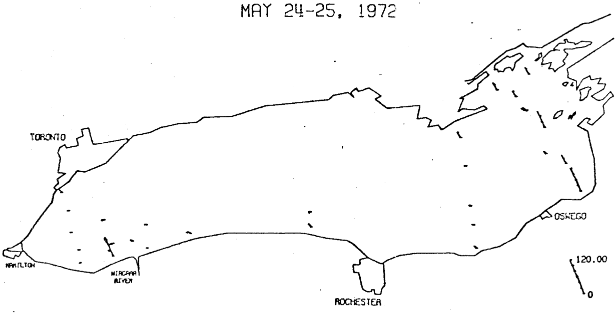


FIG. 7. Areal distribution of 80-150 μm particles.

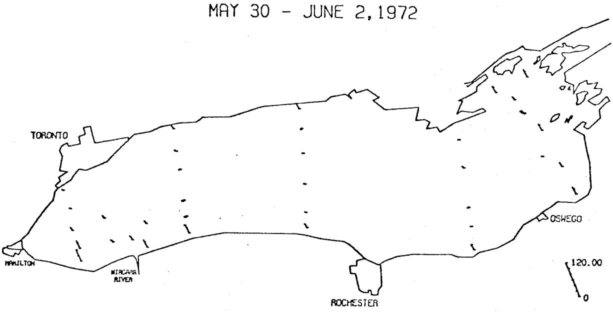


C

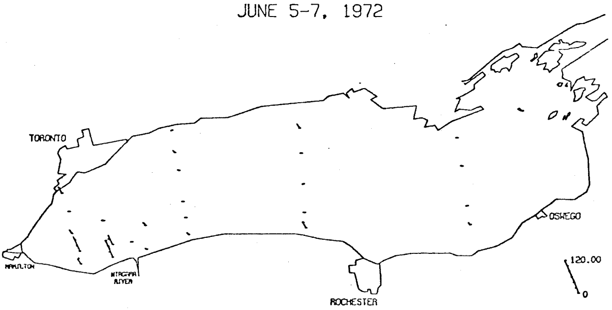


D

FIG. 7 continued.



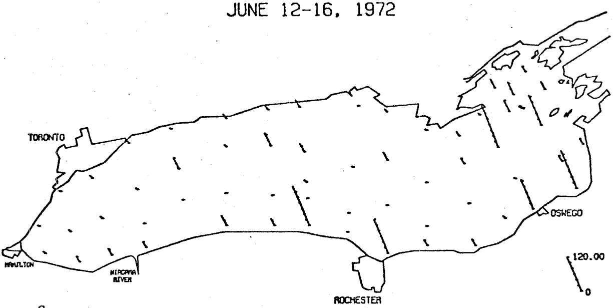
E



F

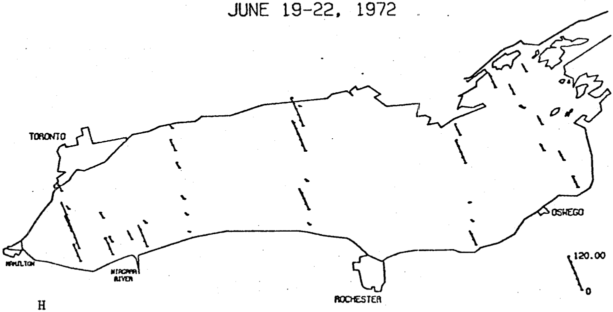
FIG. 7 continued.

JUNE 12-16, 1972



G

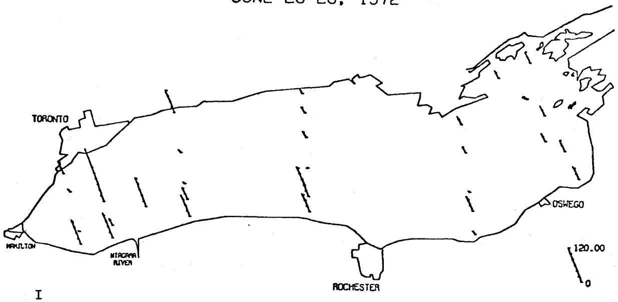
JUNE 19-22, 1972



H

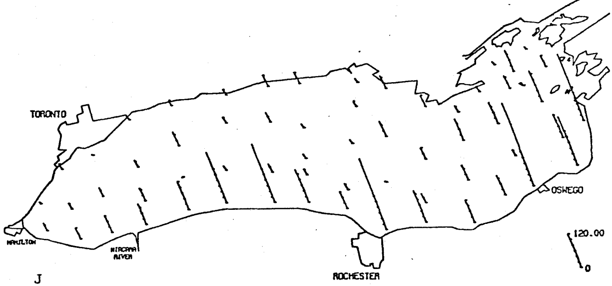
FIG. 7 continued.

JUNE 26-28, 1972



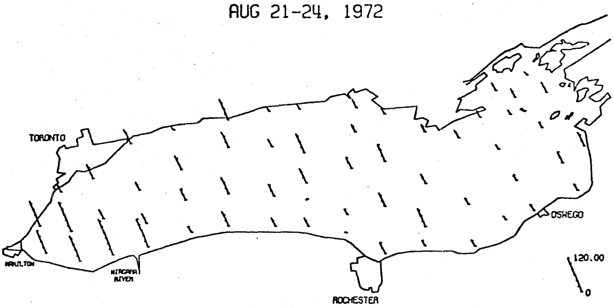
I

JULY 10-14, 1972

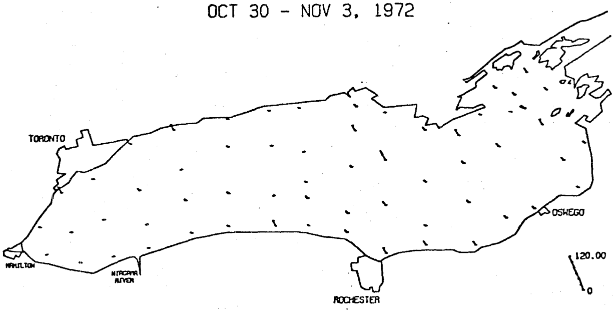


J

FIG. 7 continued.

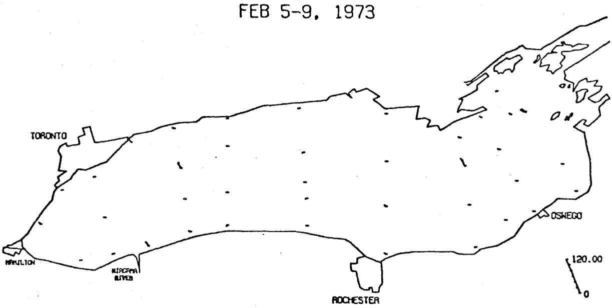


K

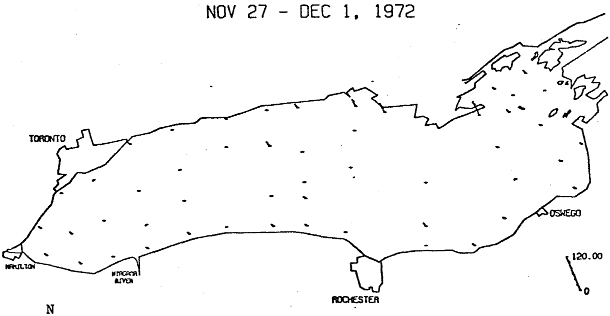


L

FIG. 7 continued.



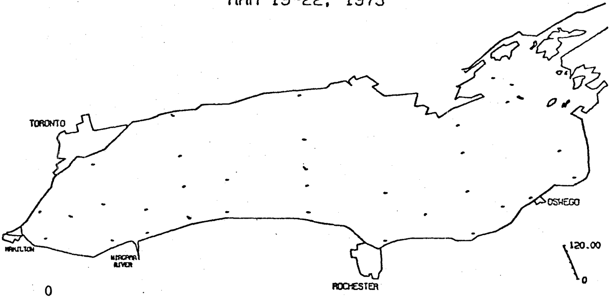
M



N

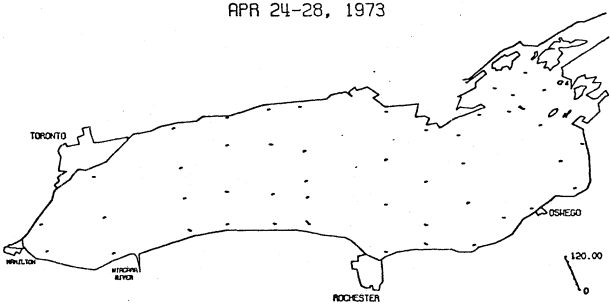
FIG. 7 continued.

MAR 19-22, 1973



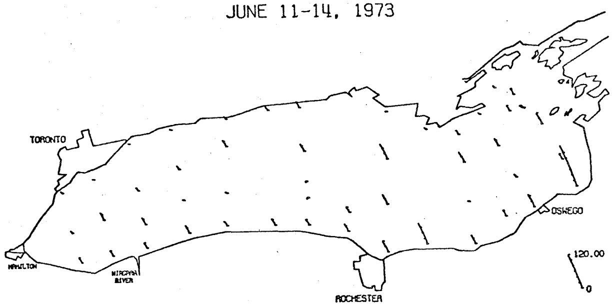
O

APR 24-28, 1973



P

FIG. 7 continued.



Q

FIG. 7 continued.

Hamilton-Niagara region. Particle densities in this size range declined drastically by October (Fig. 7L) and remained low during the winter and spring (Fig. 7M, N, O, P). A substantial increase was noted in June samples (Fig. 7Q), but levels approaching those common the previous year were present only at a single station in Mexico Bay.

Vertical Distribution by Size Class

The vertical distribution of 5-10 μm particles at stations sampled on the main lake biology-chemistry cruises is plotted in Figure 8. Stations sampled during May showed relatively little vertical stratification, although samples from stations 42, 72, 73, 59, 79, and 90 showed a definite vertical trend in abundance. Stations sampled during June 1972 showed more or less pronounced vertical stratification, except stations 26, 32, 40, 44, 62 and 75 which had very low counts and no apparent vertical trend. Similar vertical distribution was noted at stations 15, 45, 46 and 54 but particle densities at these stations were somewhat higher. Very similar patterns, possibly indicative of regional water mass similarities, were noted at stations 30 and 31 and at stations 52, 64, and 66. All stations sampled during July showed some evidence of vertical stratification, and some apparent regional patterns were evident. At stations 5, 10, 24, and 26, 5-10 μm particles were appreciably concentrated at

10 m while at stations 38, 40, 44, and 45 there appeared to be a distinct break in concentration levels at the 20 m depth. Somewhat surprisingly, samples taken during August did not show as distinct vertical patterns as the samples from previous months, perhaps as a result of a floristic shift of species in the larger size classes. At this time similar patterns were noted at stations 45 and 46, although adjacent station 44 was strikingly different. Stations 62, 64 and 69 showed a different but internally consistent pattern. Stratification of particles in this size class apparently broke down in October and, as would be expected, no trends were evident in the winter and early spring samples. In April, anomolous results were obtained at station 26. Samples from the June 1973 cruise showed an unusual pattern at the same station when particle densities that were down to 40 m then increased. A similar pattern was found at station 44. Apparently similar vertical distributions were found at stations 46, 62, 64, and 66, but results from this sampling period were, in general, much more irregular than in the same month the previous year.

Vertical distributions of 10-20 and 20-40 μm particles are plotted in Figure 9. May samples showed significant stratification of particles in these size categories at stations 30, 31, 72, and 73 along the south shore, stations 94, 96, 97, and 98 in the eastern island area, and station 105 in Mexico Bay. Other stations sampled showed little significant stratification. Stratification of particles in these size ranges

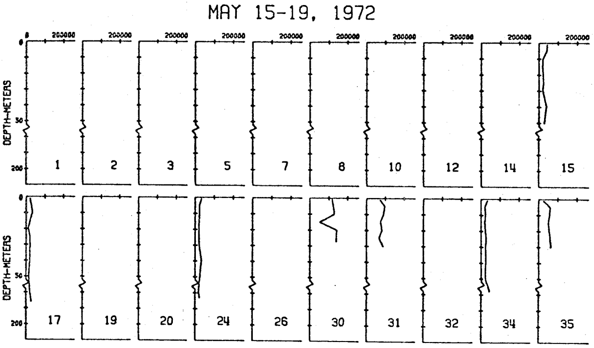
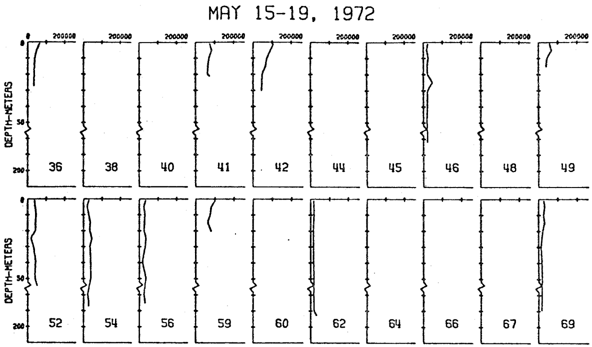


FIG. 8. Vertical distribution of 5-10 μm particles.



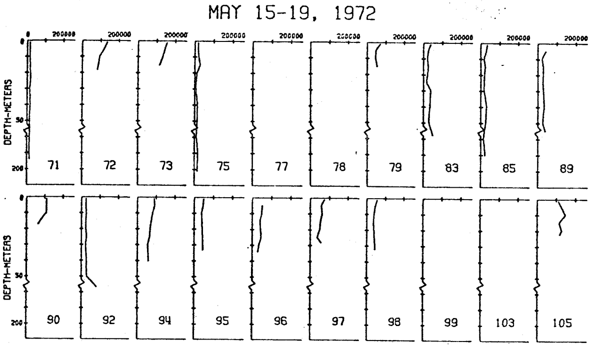
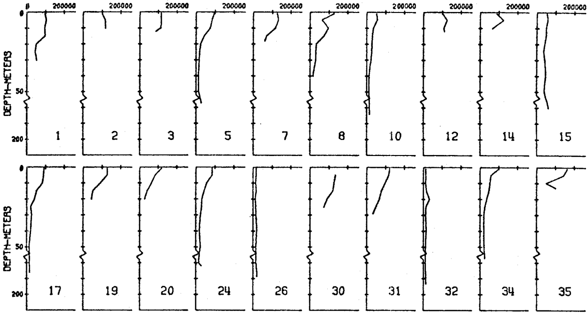


FIG. 8 continued.

JUNE 12-16, 1972



JUNE 12-16, 1972

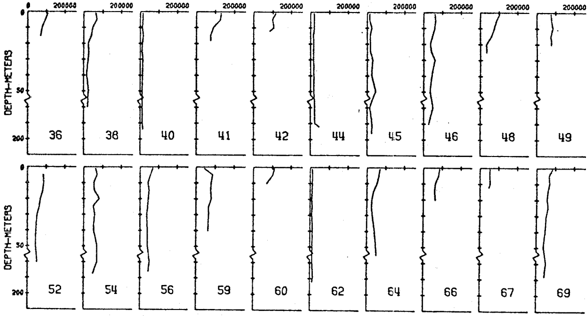


FIG. 8 continued.

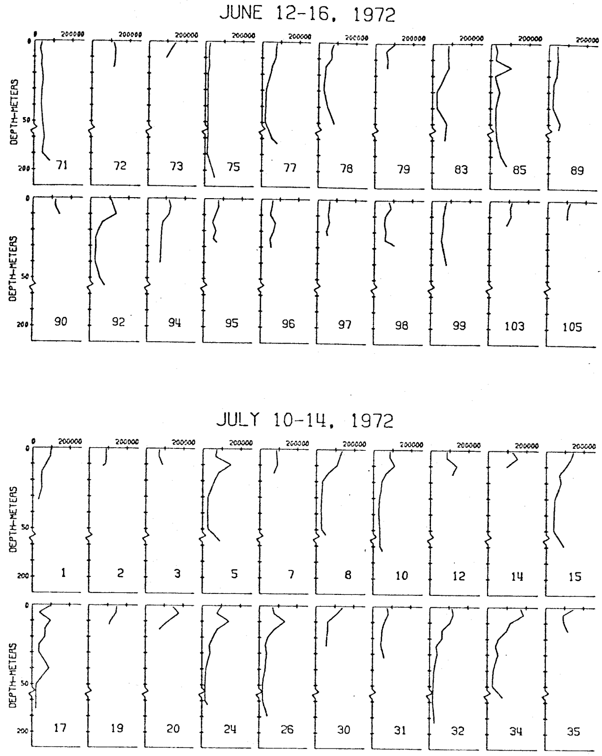
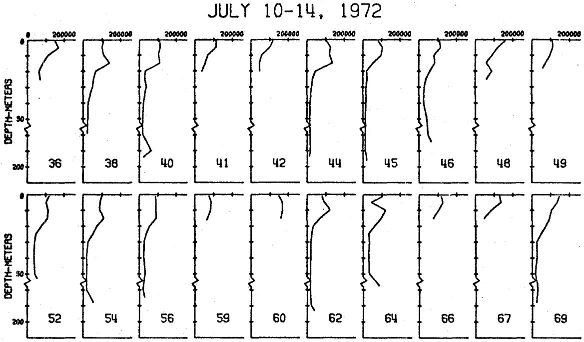


FIG. 8 continued.



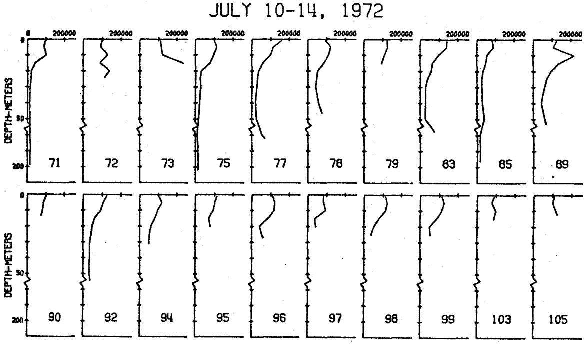
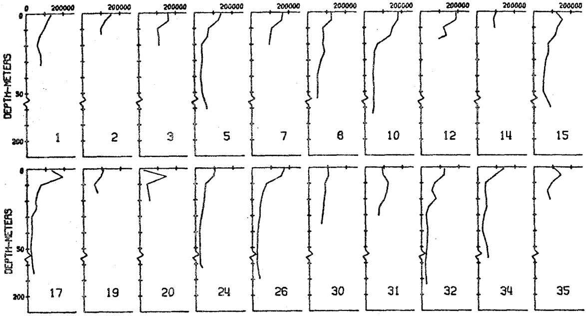


FIG. 8 continued.

AUGUST 21-24, 1972



AUGUST 21-24, 1972

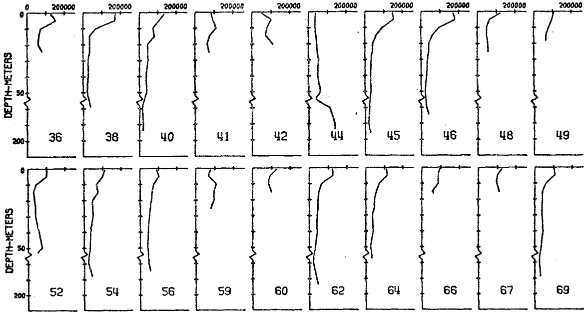
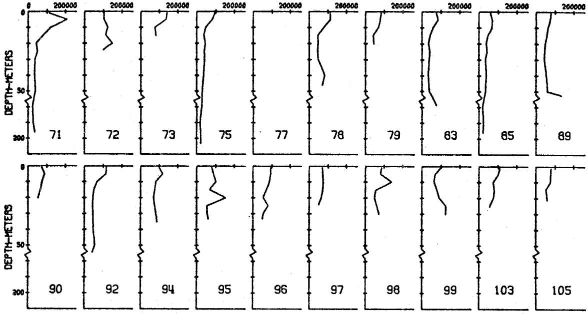


FIG. 8 continued.

AUGUST 21-24, 1972



OCT 30 - NOV 3, 1972

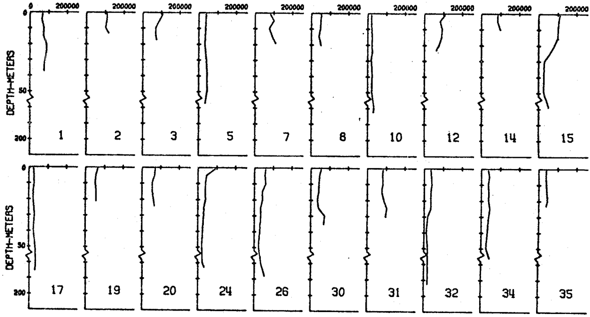
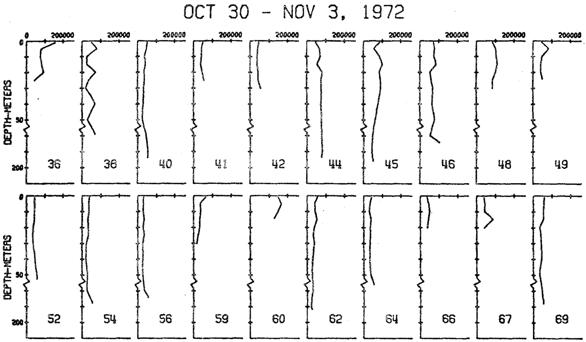


FIG. 8 continued.



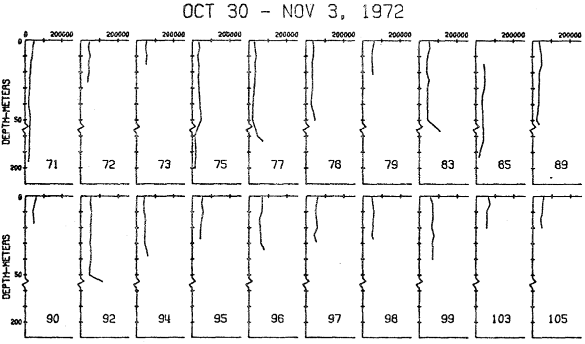
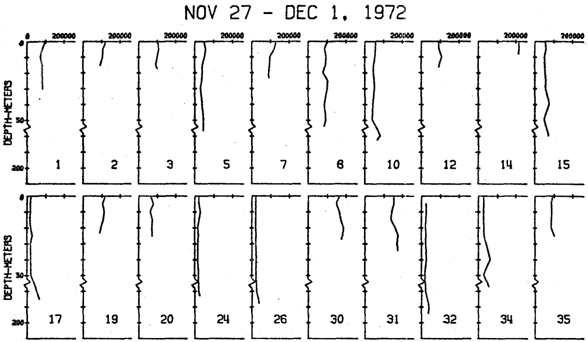


FIG. 8 continued.



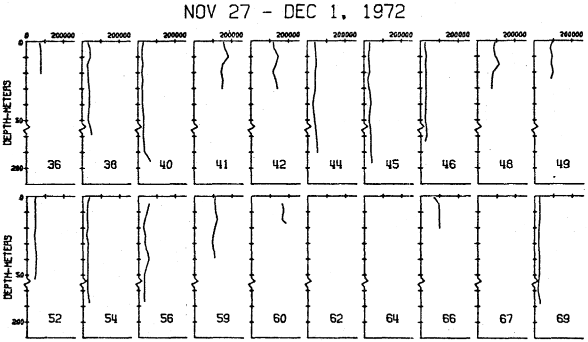


FIG. 8 continued.

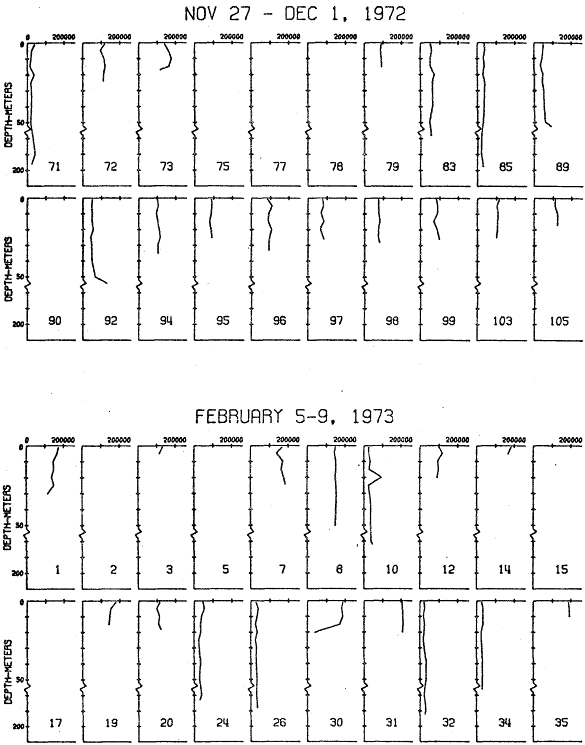
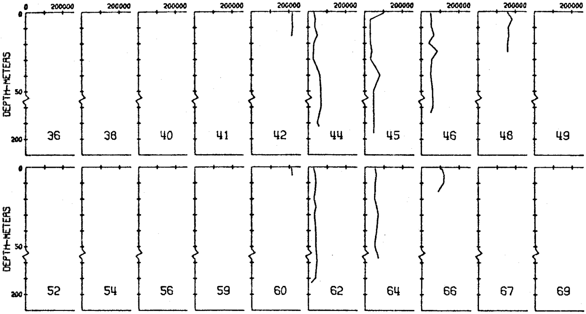


FIG. 8 continued.

FEBRUARY 5-9, 1973



FEBRUARY 5-9, 1973

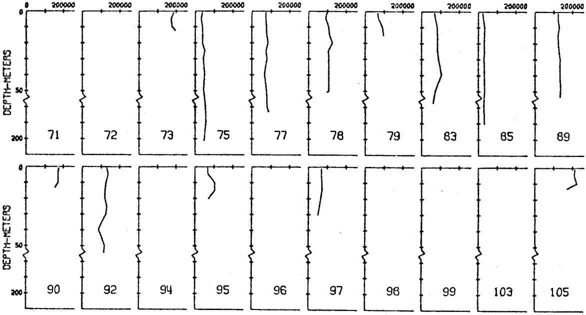
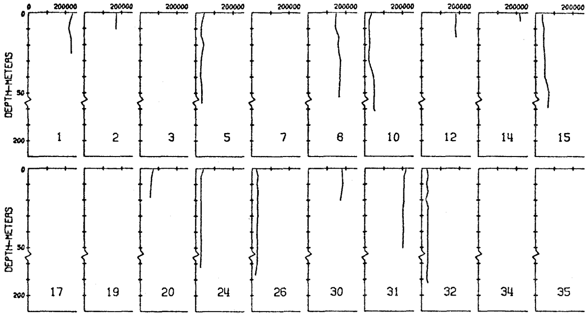


FIG. 8 continued.

MARCH 19-22, 1973



MARCH 19-22, 1973

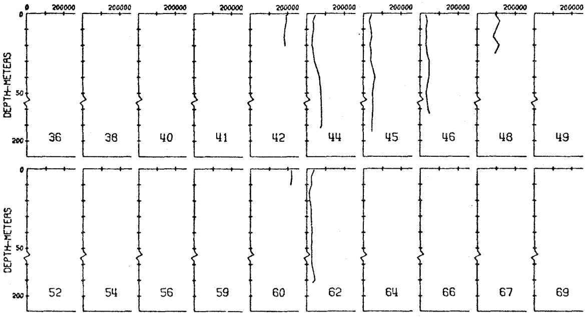


FIG. 8 continued.

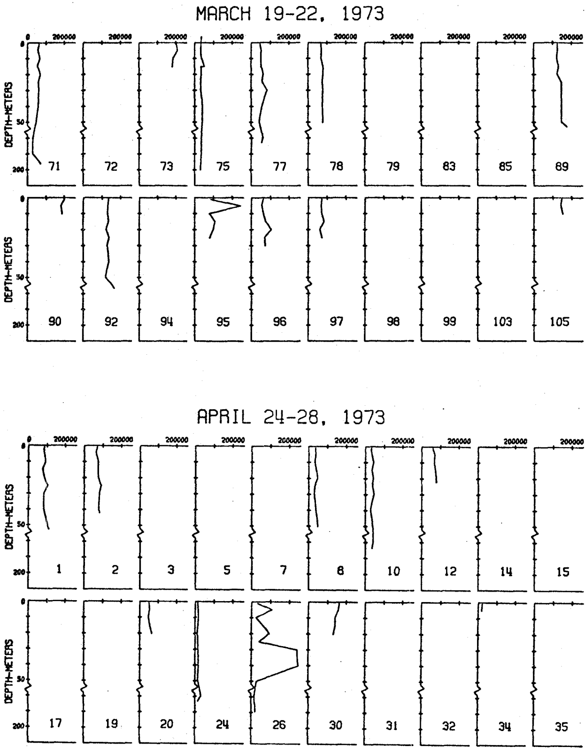
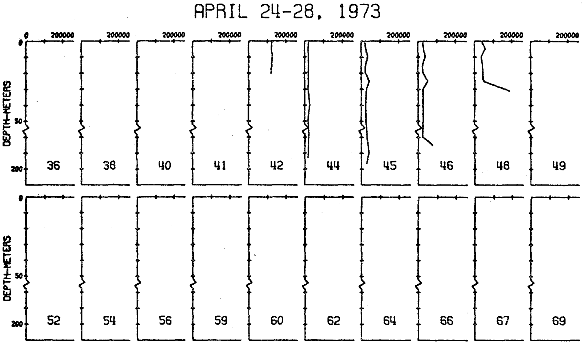


FIG. 8 continued.



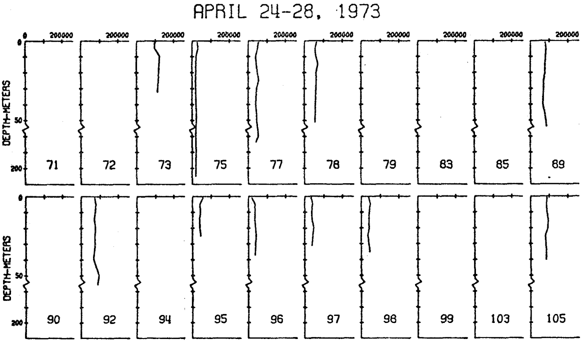
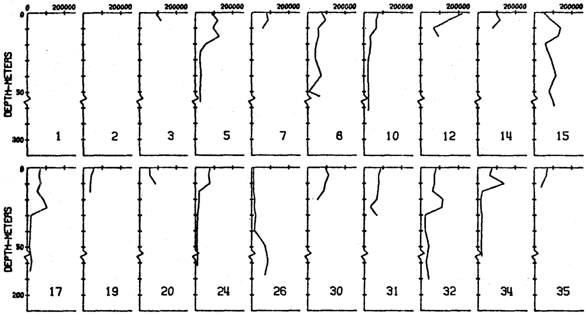


FIG. 8 continued.

JUNE 11-14, 1973



JUNE 11-14, 1973

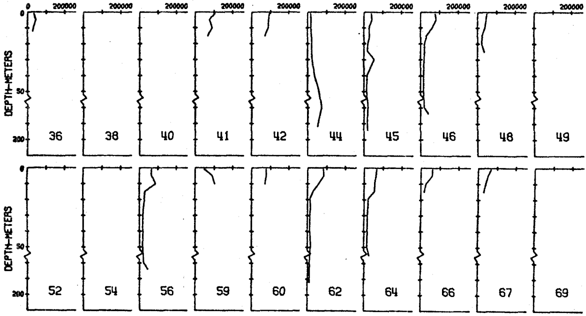


FIG. 8 continued.

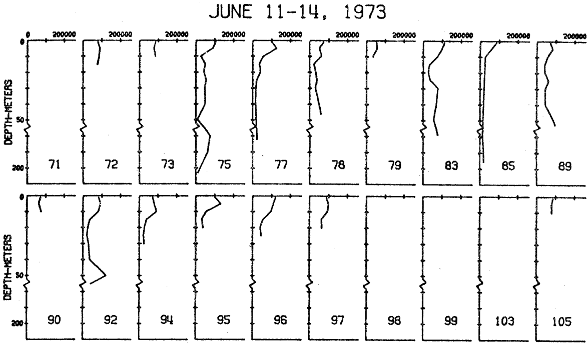


FIG. 8 continued.

was rather poorly developed at stations sampled during the June 1972 cruise, and significant vertical differences were mostly restricted to stations near shore and in the eastern part of the lake. Samples taken from station 75 during this cruise showed unusually high particle count values in the near-bottom waters. Many stations sampled during July had highest particle count values and significant peaks in particle density at depths ranging from 10 to 20 m, and particle densities were higher in the upper water column at most stations sampled. An appreciable secondary peak was noted at 50 m at station 56. Samples taken during August all showed higher concentrations of particles in this size category in the epilimnion, and there was an extreme peak at 15 m at station 40. Certain stations showed relatively high concentrations in the near-bottom waters. Concentration of particles in these size categories was relatively low in samples taken during October, and most stations had relatively insignificant vertical differences. Station 15 was an exception in that vertical stratification in particle density appeared still to be present. Samples from the November cruise showed unusually high particle densities in the near-bottom waters at stations 30 and 31. Samples taken during this cruise from many of the stations in the eastern part of the lake were unusual in that the ratio between abundance of 10-20 and 20-40 μm particles was reversed from the normal case throughout the rest of the year. In February and March, however, concentration of 10-20 μm particles exceeded the average ratio. In

April, samples from station 26 had very unusual values, as they did in the lower particle count channel, and unusually high near-bottom values were found at stations 45, 46, and 48. In June 1973, particle count values were higher in the top 20 meters, although more variation was present than had been the case the previous year. Station 26 had unusually high values in the deep-water samples, and surrounding stations had extreme peaks at 20 m (sta. 17) and 40 m (sta. 15 and 32).

Samples taken during the May 1972 cruise (Fig. 10) showed near-surface concentrations of particles in the 40-80 and 80-150 μm size classes at stations 94, 96, and 97 in the eastern end of the lake and station 105 in Mexico Bay. Mid-lake stations 17, 34 and 46 showed relatively high subsurface values in the 10-30 m range. In June 1972, most stations sampled showed stratification of particles in these size classes, with highest values occurring near the surface. There were, however, a series of about 14 stations in the south central "cold core" region of the lake where counts were appreciably lower and stratification was not highly developed. Stations sampled during July all showed stratification near the surface but no particular regional trends were evident. In August, values remained relatively high, with greatest concentrations near the

MAY 15-19, 1972

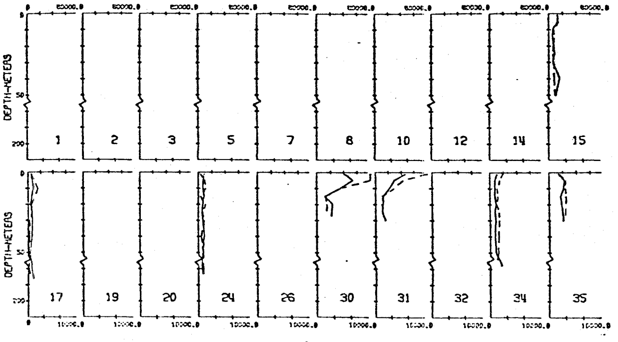
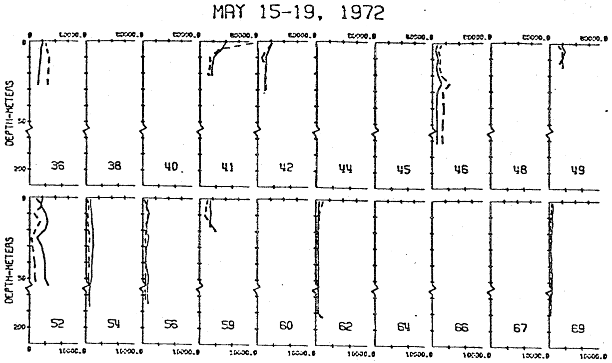


FIG. 9. Vertical distribution of 10-20 μm and 20-40 μm particles. The 10-20 μm channel is represented by the solid line and the upper scale, the 20-40 μm channel by the dashed line and the lower scale. A star indicates that an entire profile is above the maximum scale value.



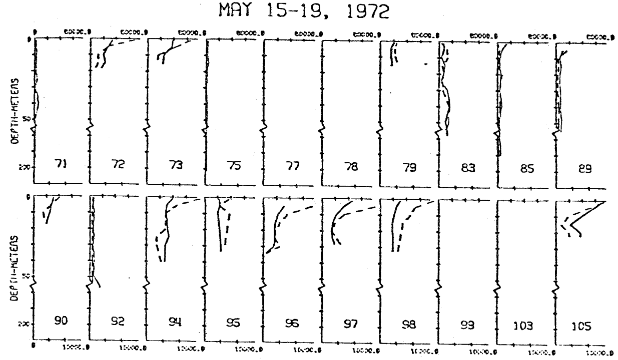
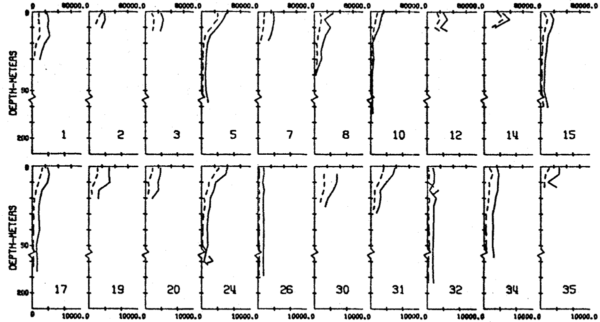


FIG. 9 continued.



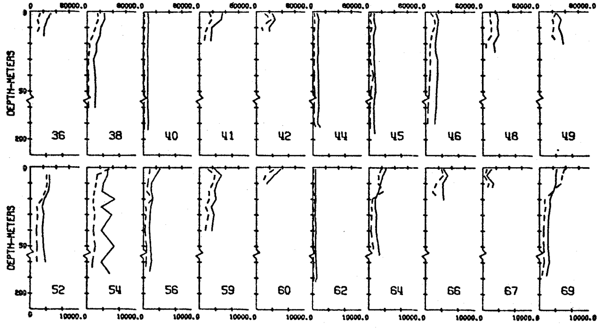
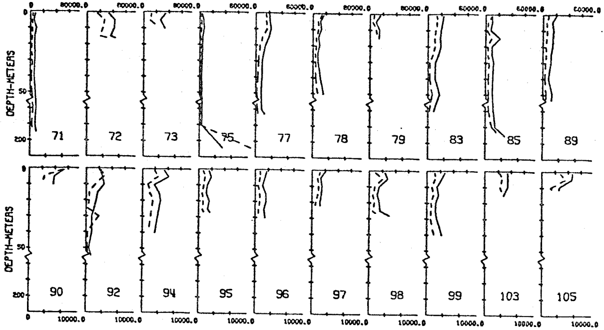
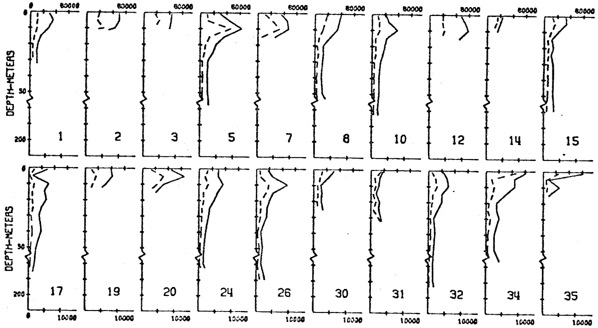


FIG. 9 continued.

JUNE 12-16, 1972



JULY 10-14, 1972



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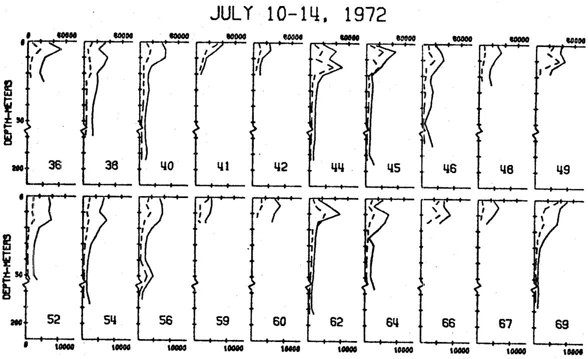

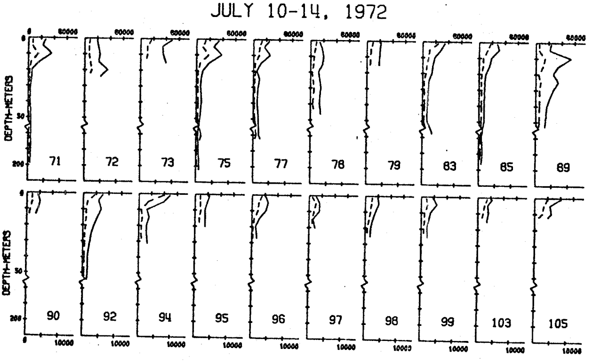

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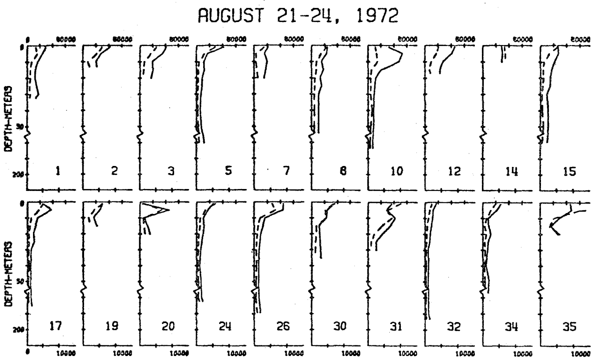


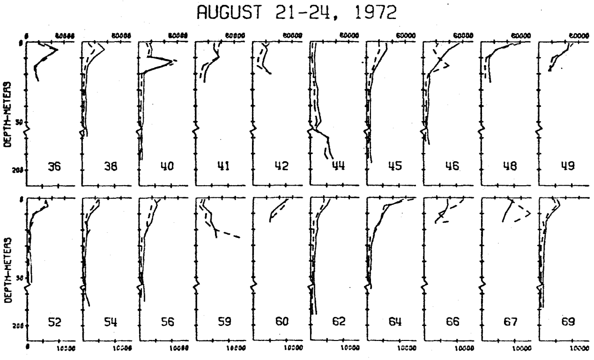
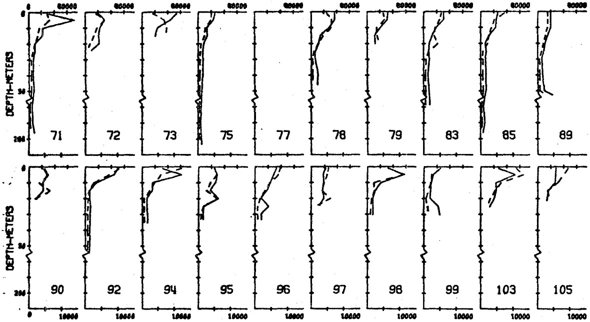


FIG. 9 continued.

AUGUST 21-24, 1972



OCT 30 - NOV 3, 1972

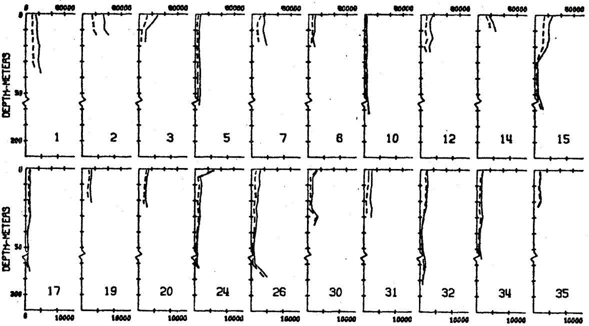
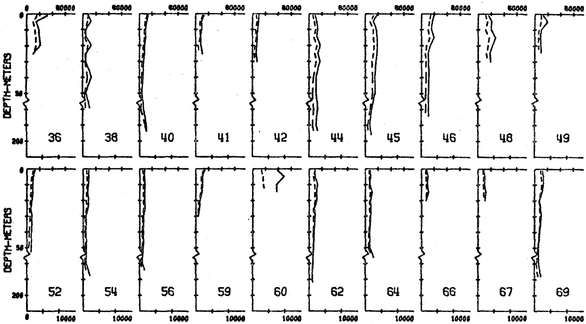


FIG. 9 continued.

OCT 30 - NOV 3, 1972



OCT 30 - NOV 3, 1972

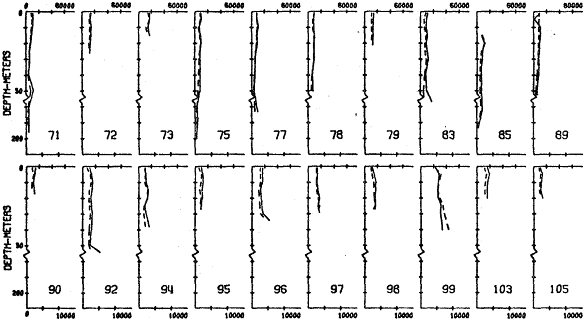
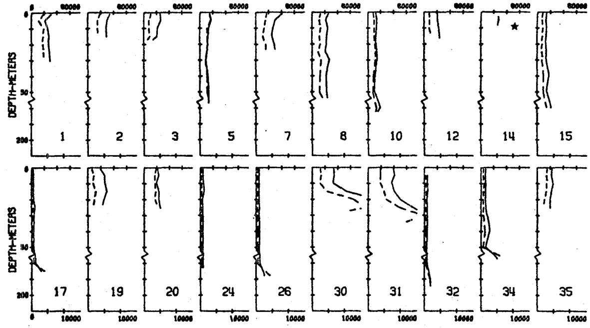


FIG. 9 continued.

NOV 27 - DEC 1, 1972



NOV 27 - DEC 1, 1972

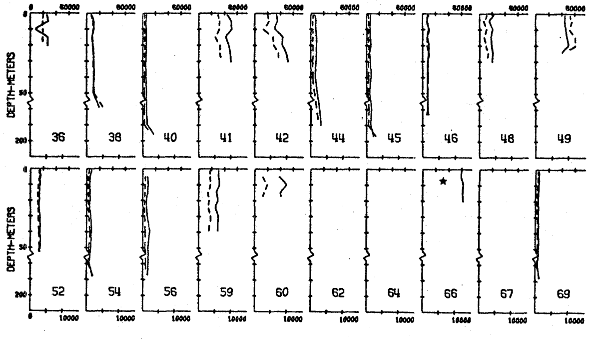


FIG. 9 continued.

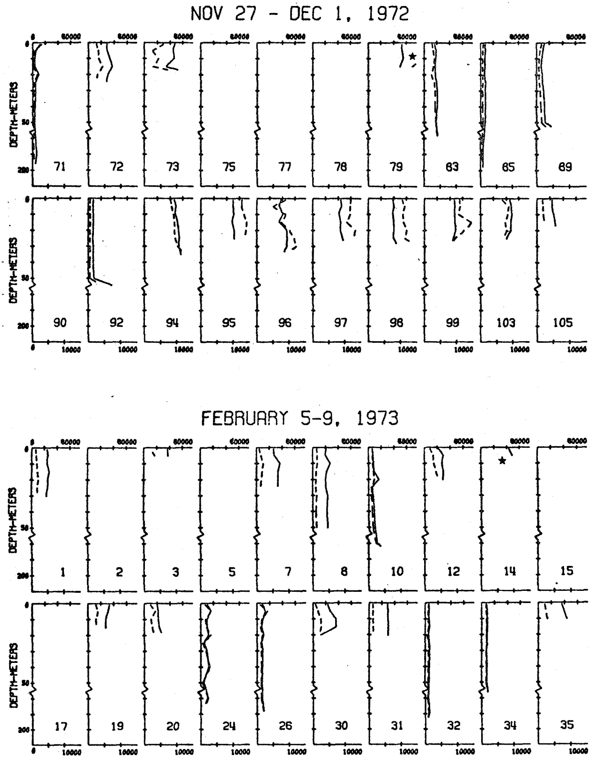
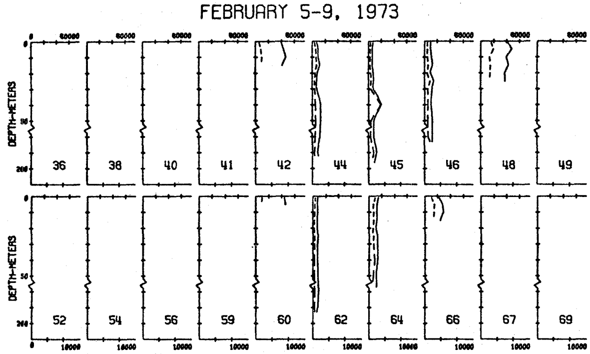
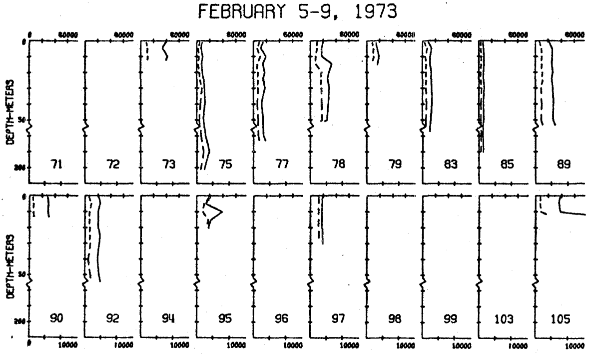


FIG. 9 continued.





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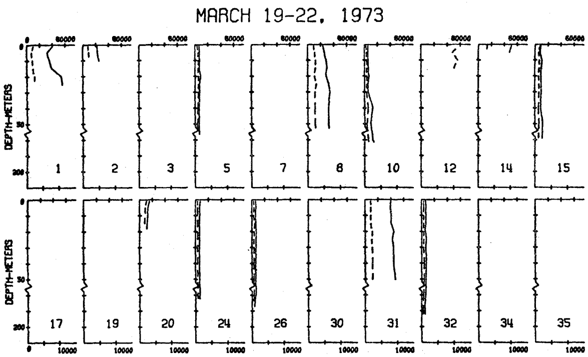

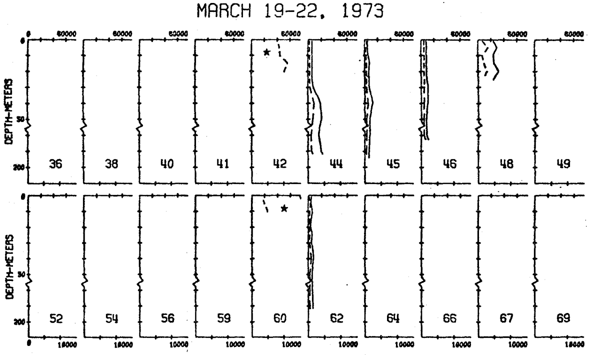

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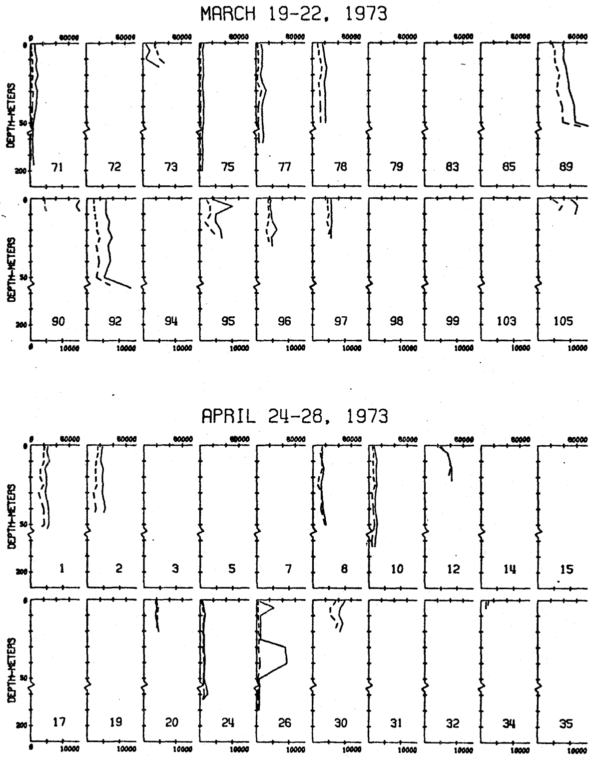
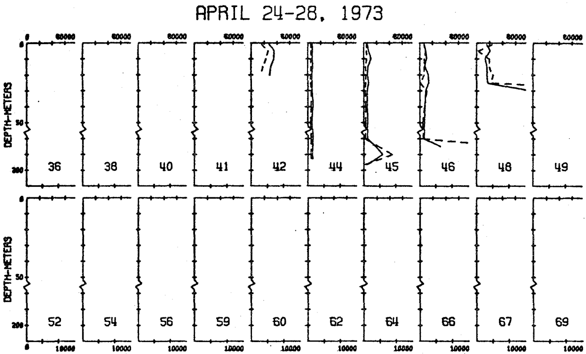


FIG. 9 continued.



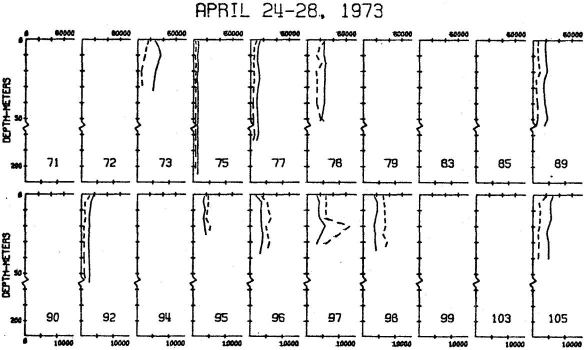
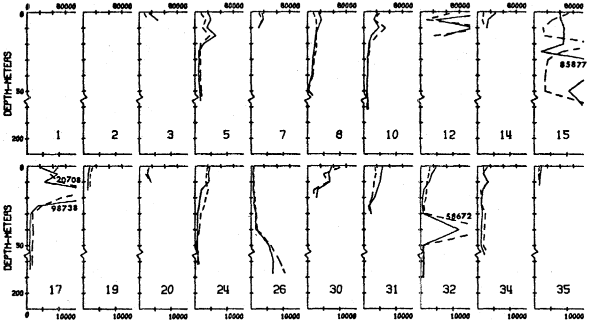
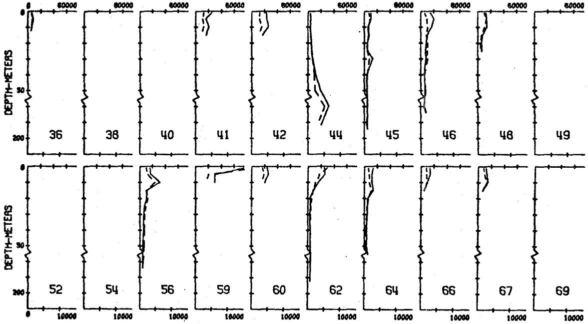


FIG. 9 continued.

JUNE 11-14, 1973



JUNE 11-14, 1973



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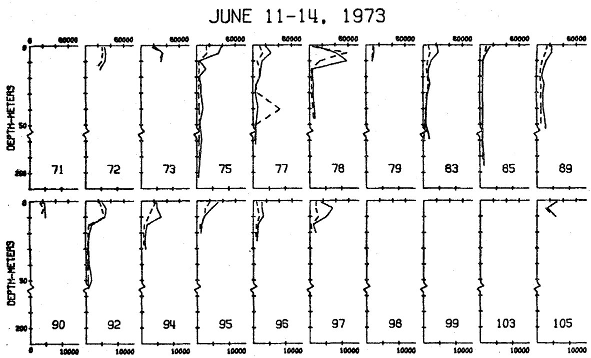
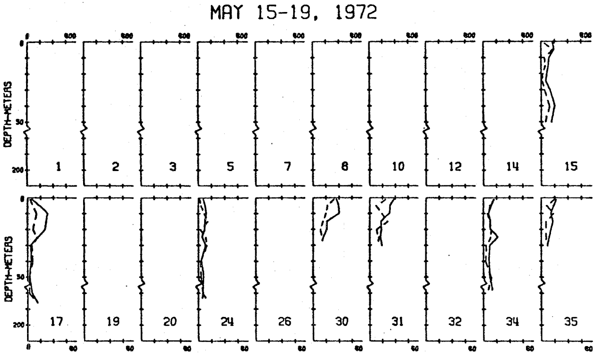


FIG. 9 continued.

surface except at station 40, where a large peak was noted at 15 m and station 59 where values were very high in the near-bottom sample. In October, values were reduced and stratification was less pronounced at all stations sampled. Subsurface peaks were noted at station 30 (near bottom), station 94 (20 m) and station 99 (5 and 10 m). As might be expected, samples taken during November 1972 showed relatively little vertical stratification. Very high near-bottom values were noted at stations 26, 30, 31, 32, 34, 36, and 38. Similar to some of the other channels, there was an evident change in channel ratios at all depths sampled at station 49 and stations 94-99 and 103 in the far eastern area of the lake. Stations collected during February 1973 had relatively low values, although samples from the upper 20 m were significantly higher at station 24, and 5 m peaks were noted at stations 20 and 26. Mid-depth peaks were noted at stations 45, 46, 75, and 89. In March, values were relatively low except at stations 12, 30, and 42 along the southeastern shore and stations 89, 92, and 95-97 in the eastern portion of the lake. Samples from the April cruise showed extreme near-bottom values at stations 45, 46, and 48 and relatively high values at stations 95-98 in the far northeastern end of the lake. High and rather variable values were found at most stations sampled during June 1973, with apparent vertical stratification being present except at stations 32, 44, and 45 where particle counts were low and there was little evidence of vertical

stratification. Mid-depth peaks were noted at stations 17 and 77.



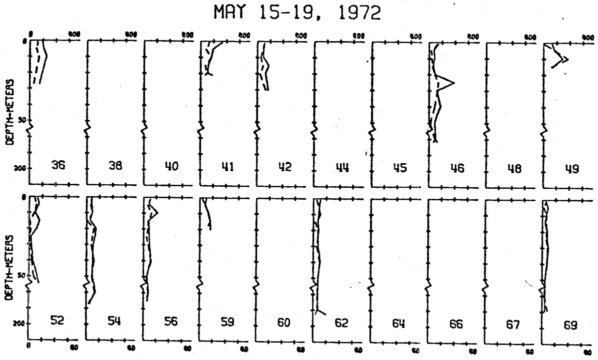


FIG. 10. Vertical distribution of 40-80 μm and 80-150 μm particles. The 40-80 μm channel is represented by the solid line and the upper scale, the 80-150 μm channel by the dashed line and the lower scale. A star indicates that an entire profile is above the maximum scale value.

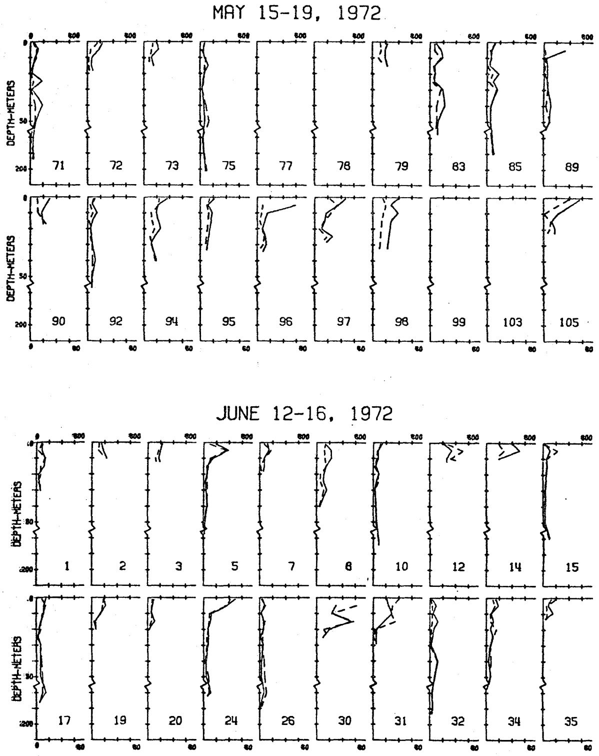
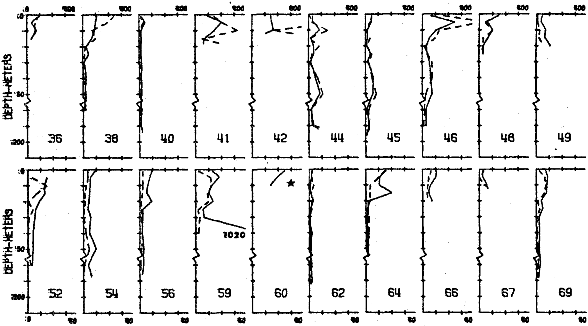


FIG. 10 continued.

JUNE 12-16, 1972



JUNE 12-16, 1972

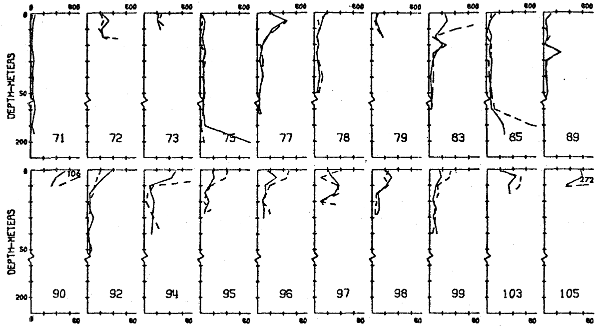
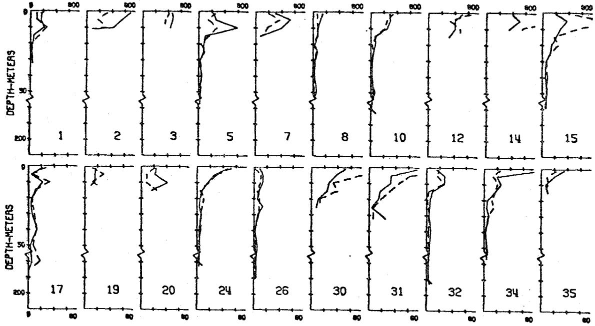


FIG. 10 continued.

JULY 10-14, 1972



JULY 10-14, 1972

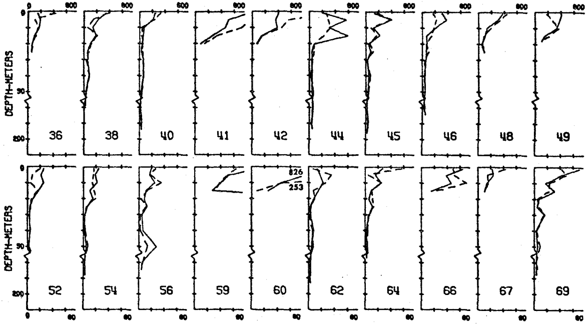
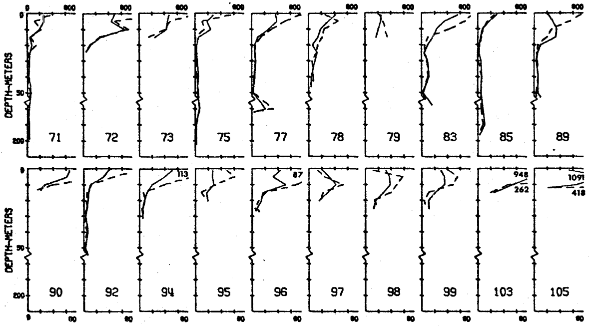


FIG. 10 continued.

JULY 10-14, 1972



AUGUST 21-24, 1972

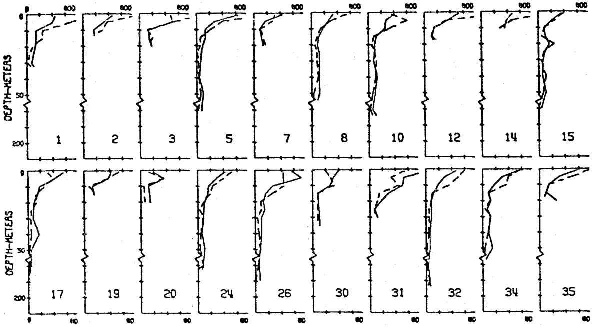
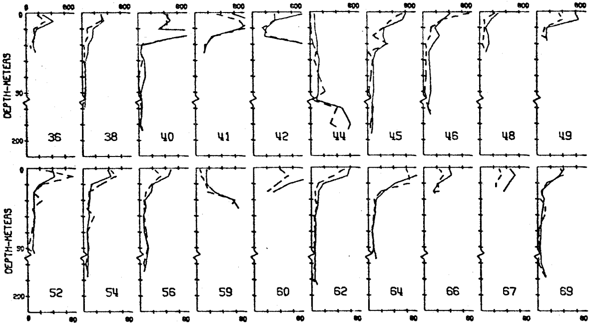
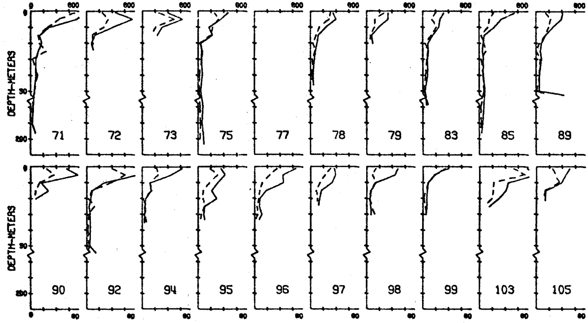


FIG. 10 continued.

AUGUST 21-24, 1972



AUGUST 21-24, 1972



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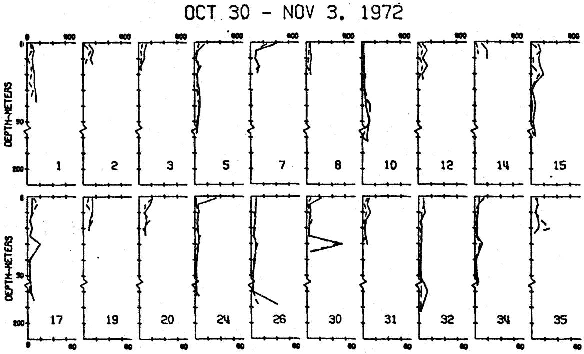

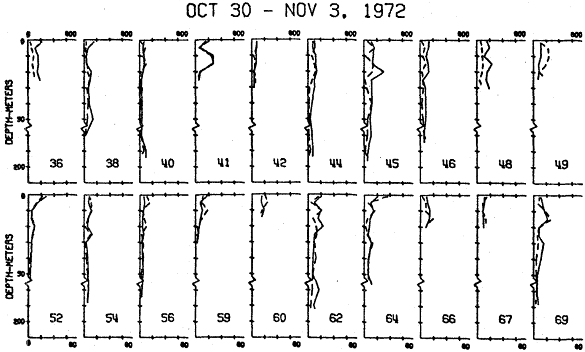

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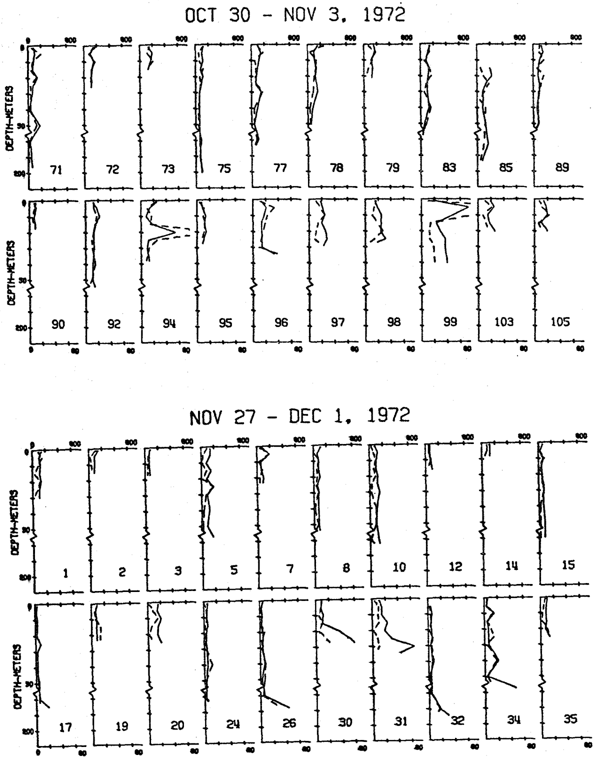
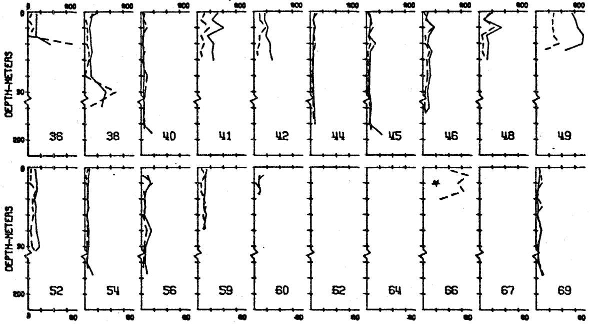


FIG. 10 continued.

NOV 27 - DEC 1, 1972



NOV 27 - DEC 1, 1972

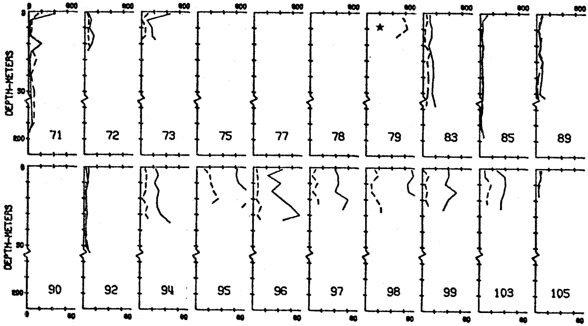
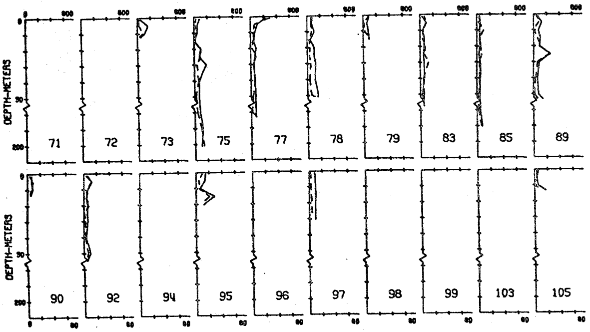
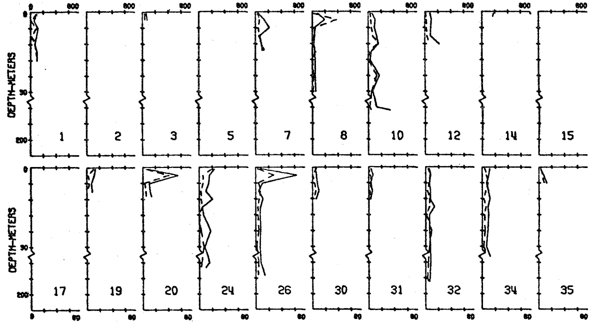


FIG. 10 continued.

FEBRUARY 5-9, 1973



FEBRUARY 5-9, 1973



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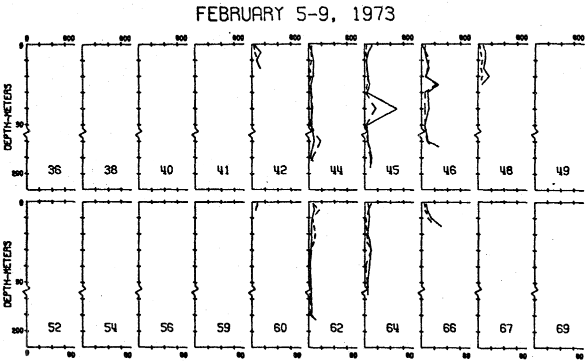


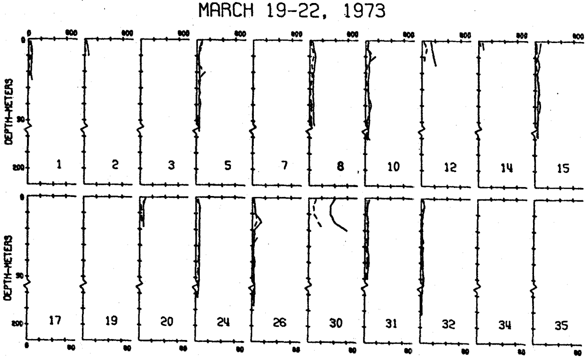
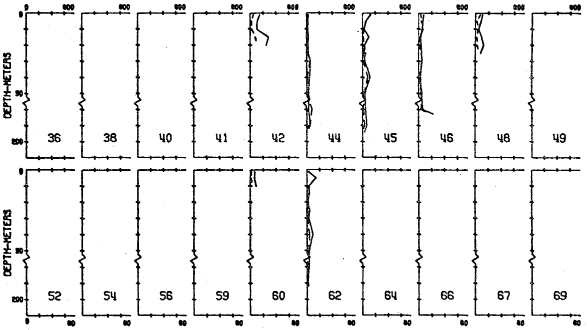


FIG. 10 continued.

MARCH 19-22, 1973



MARCH 19-22, 1973

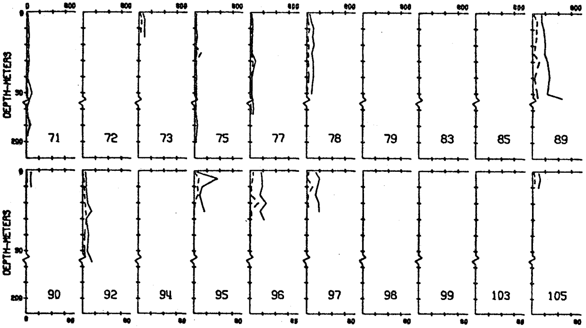
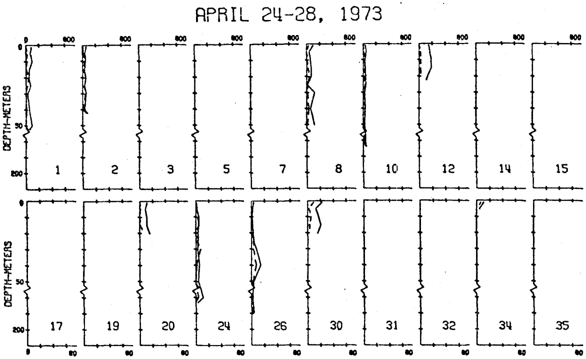


FIG. 10 continued.



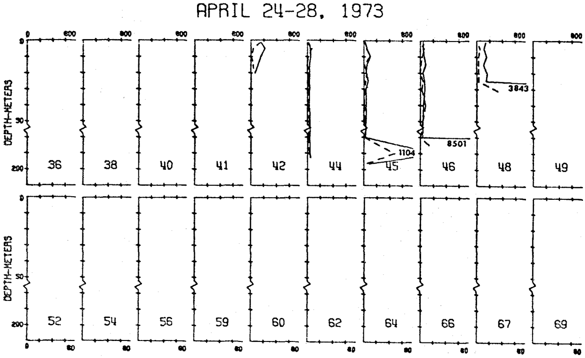
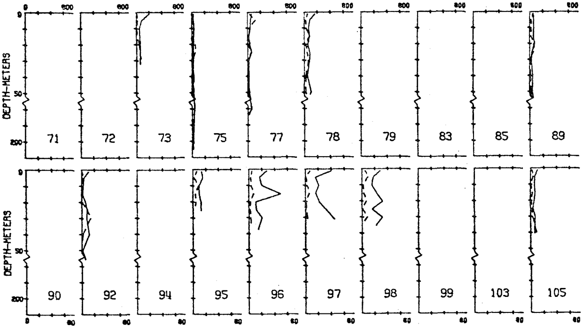


FIG. 10 continued.

APRIL 24-28, 1973



JUNE 11-14, 1973

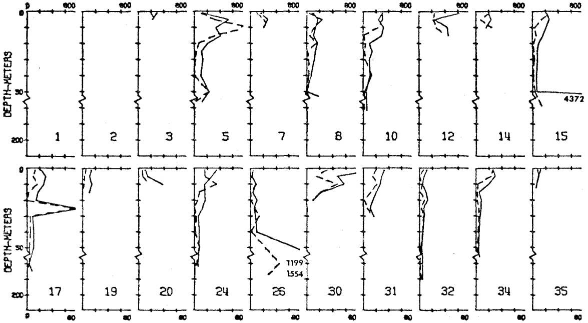
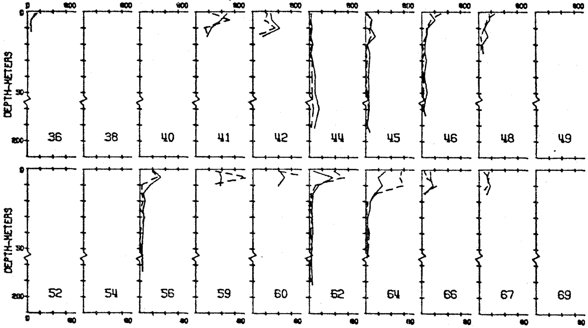


FIG. 10 continued.

JUNE 11-14, 1973



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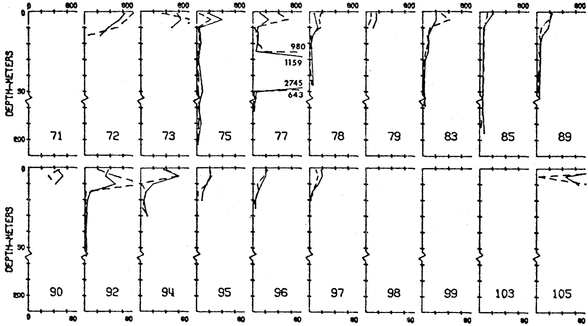


FIG. 10 continued.

PHYTOPLANKTON DATA

Areal Distribution of Total Phytoplankton in Near-surface Waters

Trends in total phytoplankton abundance in the surface waters of Lake Ontario are summarized in Figure 11.

Based on samples taken during the May 1972 cruise, there appeared to be a nearshore bloom with largest standing crops occurring at relatively shallow stations nearest shore and in the eastern part of the lake. Highest values were found at stations on the southeastern shore, especially near Sodus Bay and in Mexico Bay, although nearly comparable values were found at some stations in the northeastern island area. By the time the June 1972 samples were taken, high phytoplankton standing crop levels had become more generally distributed in the lake and highest abundance values were found at stations in the northwestern sector.

Some reduction in abundance was noted at stations on the southern shore which had highest levels the previous month. There was also an apparently consistent trend toward low total phytoplankton abundance at a series of stations offshore in the south central part of the lake. In July, average phytoplankton cell counts were reduced, but there was a tendency for highest values to be found at stations in the southern half of the lake. One particularly high abundance value was noted at station 14, near Niagara. A slight further reduction in total cell abundance was noted in the August samples, and highest values were found at stations in the southern and eastern sectors of the lake. In this respect the situation this month was somewhat similar to that found in early spring, although the tendency towards extremely high values at stations nearest shore was not nearly as pronounced.

A continued reduction in total phytoplankton abundance was found in the October samples, and this month no pronounced regional distribution patterns were evident although peak values were generally found at mid-lake stations. Total phytoplankton abundance apparently continued to decline in November and although highest values were still found in the offshore waters, relatively small differences were present between the stations sampled. Lowest total abundance found during our study occurred in the February samples. At this time very low phytoplankton standing crop was present at most stations sampled, with only significant highs at 79, 96, and 97, near Prince Edward Point. The apparent initiation of the spring bloom is evident from samples collected during March. Highest phytoplankton cell counts are restricted to stations nearest shore, except for those stations in the shallow northeastern part of the lake where values comparable to those found at stations nearest shore in the main part of the lake were found. This trend apparently continued as, by the time the April samples were taken, all stations

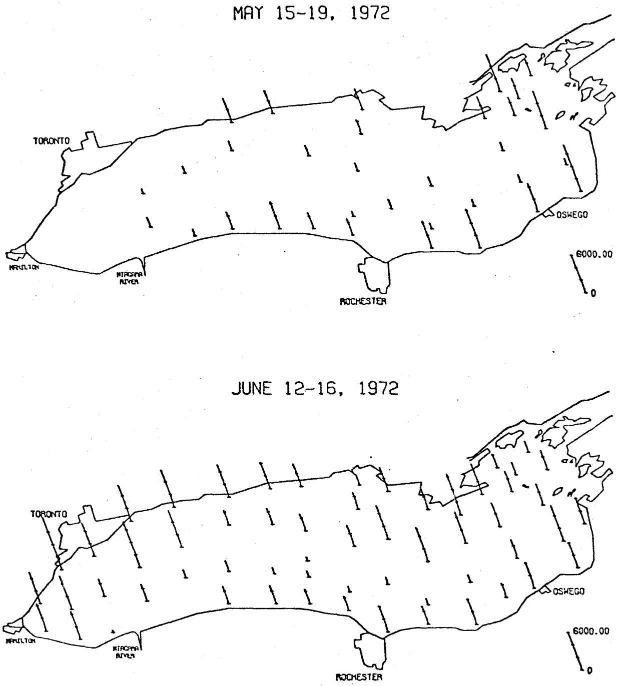
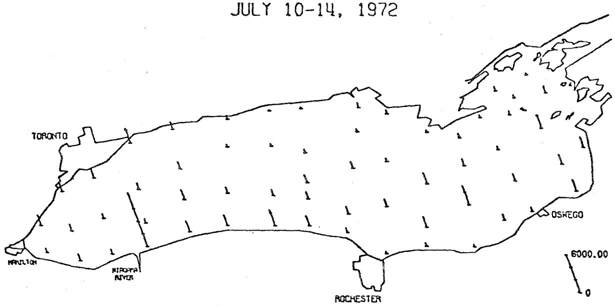


FIG. 11. Areal distribution of total cell counts.

JULY 10-14, 1972



AUGUST 21-24, 1972

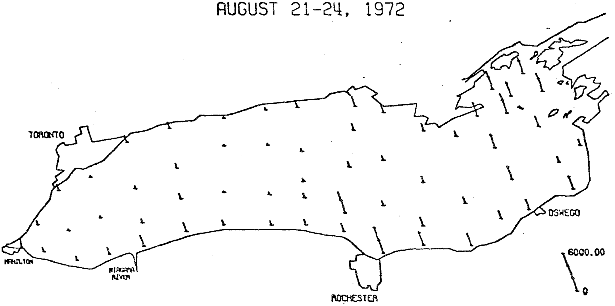
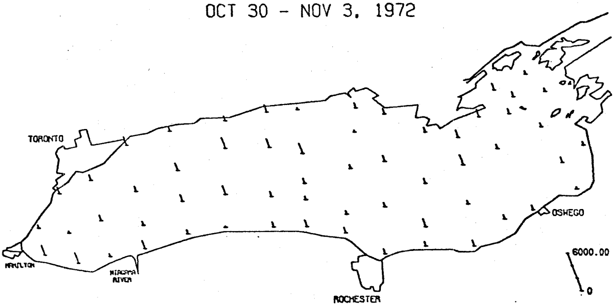


FIG. 11 continued.



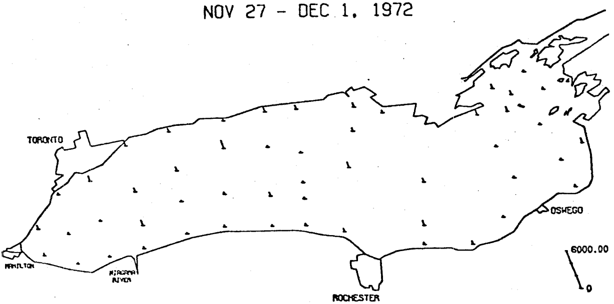
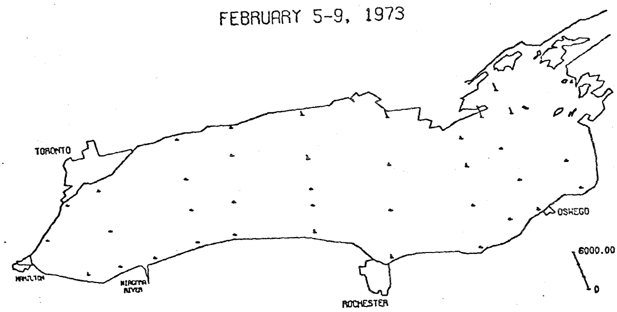


FIG. 11 continued.



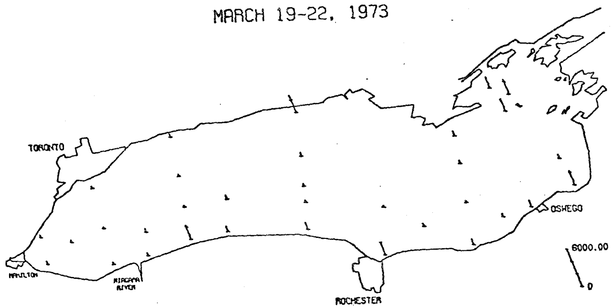
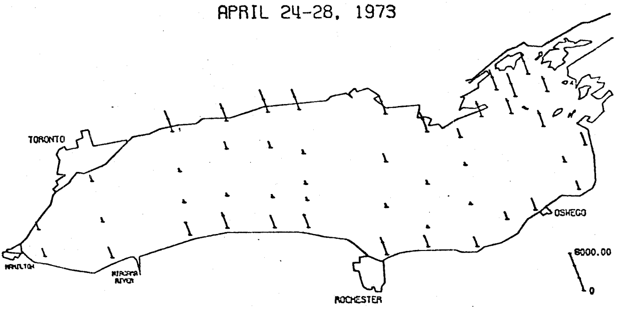


FIG. 11 continued.



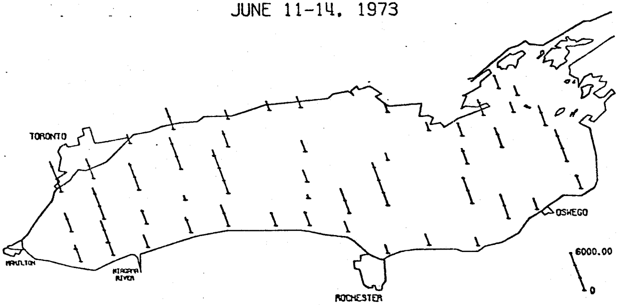


FIG. 11 continued.

nearest shore in the main body of the lake and stations north and east of a line between Prince Edward Point and Stoney Point had notably increased total phytoplankton counts. Increases were also noted at several stations in the open lake and, as in the previous spring, there was a tendency towards higher values in the northern half of the lake. By June 1973, high phytoplankton abundance was present at most stations throughout the lake. In general, levels of abundance were greater at offshore stations than they were at stations nearest shore, although notably low assemblage abundance was found at stations 15 and 44 and there appeared to be a consistent pattern of relatively low values at stations in the north central portion of the lake.

Areal Distribution of Major Groups in Near-surface Waters

Seasonal trends in the abundance of major phytoplankton groups in the surface waters of Lake Ontario, averaged for all stations sampled during any particular cruise, are shown in Figure 12. Several interesting points are evident in this summary information. The first is that the gross composition appeared to be quite different during the two spring periods sampled. In 1972, diatoms were dominant during the spring and early summer, with secondary contributions by green algae, mostly *Scenedesmus bicellularis*, and microflagellates. In 1973, however, although diatoms were again dominant in the early spring, the microflagellates became dominant by June and their average abundance on a cell count basis was more than twice as high as it had been the previous year. Although the trends shown may be partially an artifact of sampling periodicity, our evidence suggests that there were considerable differences in major group composition of the phytoplankton community in the two years. The same trend is apparent in the seasonal trends of the green algae. In 1972 there was a strong peak, apparently caused by the unusual abundance of a single population, and a secondary peak in late summer which was contributed to by a number of species. No similar spring peak in abundance of green algae was detected in our 1973 samples. Our results also indicate that the peak abundance of blue-green algae occurred unusually late in the season in 1972. This component of the phytoplankton community reached its greatest abundance in October with a nearly symmetrical increase and decline on either side of the peak.

Previous studies on phytoplankton periodicity in Lake Ontario (Munawar and Nauwerck 1971) have indicated that a late fall peak in abundance of blue-green algae is not uncommon. On the basis of the same study, it would appear that the relative abundance of major groups found in 1973 may be the more typical case for Lake Ontario, since they emphasize the importance of several species of microflagellates in their collections. On the other hand they report that *Scenedesmus* was a spring dominant, as it was in our 1972 collections but not in 1973. Thus the situation is not entirely clear, and it is highly probable that in a system as highly disturbed as Lake Ontario there is no consistent yearly pattern of phytoplankton succession and the

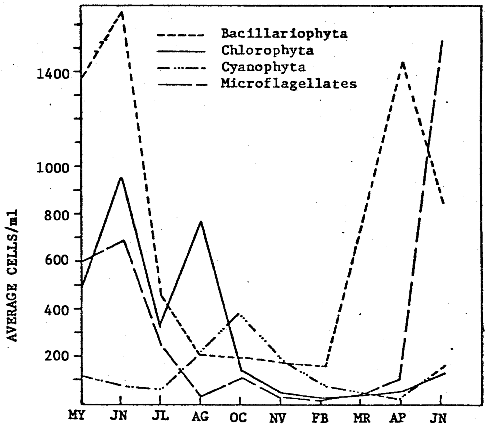


FIG. 12. Seasonal average abundance of major phytoplankton group cell counts.

events of a particular year are largely determined by yearly variations in climatic conditions, as they appear to be in western Lake Erie (Chandler 1942).

The fraction of total surface plankton contributed by the major groups is summarized in Figure 13. It was necessary to scale the figures for different months in order to accommodate the variation in assemblage density found at the different sampling periods. In our May 1972 samples diatoms were dominant at most nearshore stations in the southeastern part of the lake. Microflagellates comprised a larger fraction of the total near-surface phytoplankton at stations in the far northeastern part of the lake and at stations along the northern shore. While diatoms were dominant at some offshore stations, green algae made a more significant contribution to the total assemblage in addition to somewhat lower and more variable fractions of microflagellates. Although present at most stations sampled, the blue-green algae contributed a relatively small fraction of the total phytoplankton collected during May. A definite shift in the pattern of dominance was noted in the collections

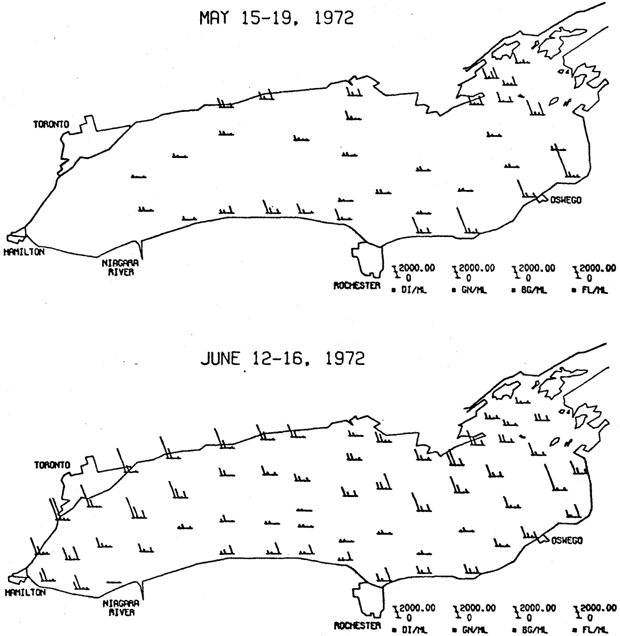
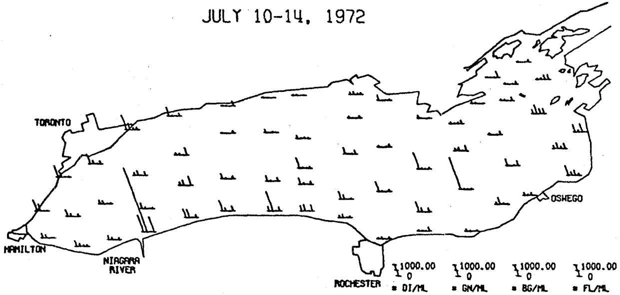


FIG. 13. Areal distribution of major phytoplankton group cell counts.



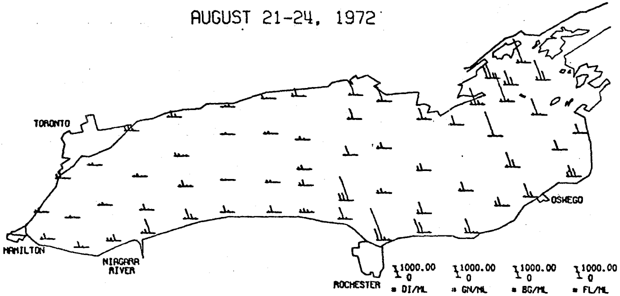
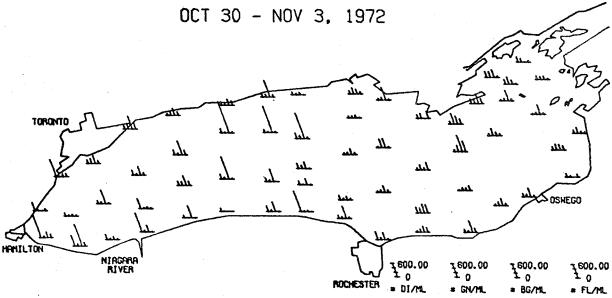


FIG. 13 continued.



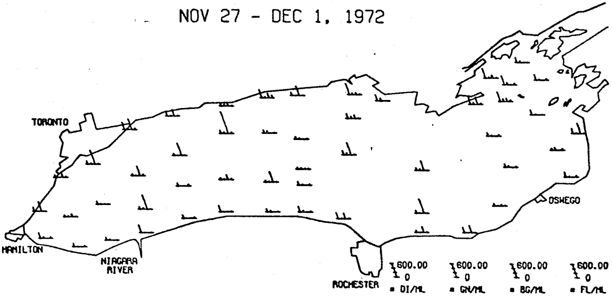
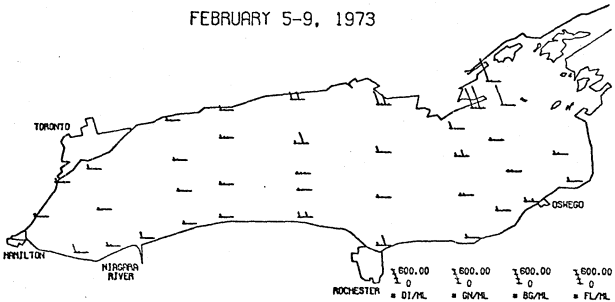


FIG. 13 continued.



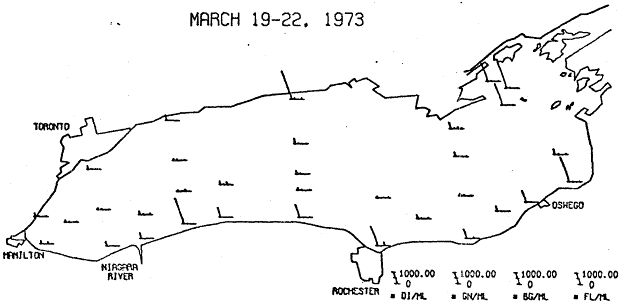
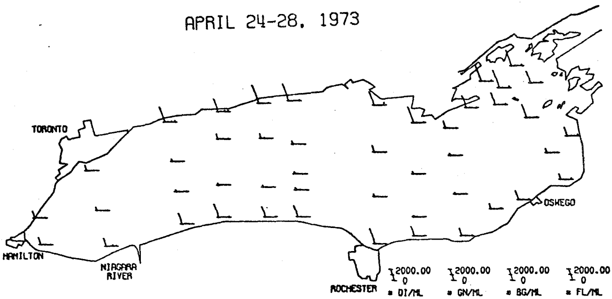


FIG. 13 continued.



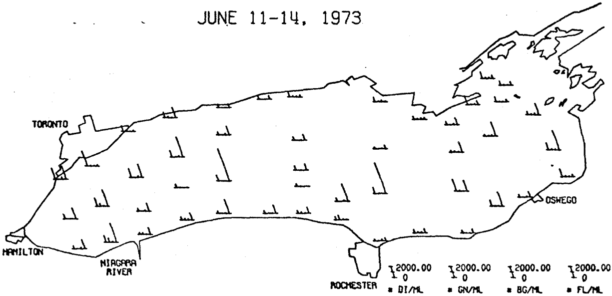


FIG. 13 continued.

taken during the June 1972 cruise. While diatoms were dominant at stations in the northwestern sector of the lake and at certain stations in the northeastern part, microflagellates had become a much more relatively important part of the flora at stations in the southeastern sector. A relative increase in the importance of green algae was seen at several stations, and they were co-dominant with the other major groups at several stations in the far southwestern and far northeastern parts of Lake Ontario. There was considerable regional variation in dominance patterns based on samples collected during July (note scale change). An extreme peak in abundance of green algae was found at station 14 near Niagara, and this group was also relatively abundant at certain stations along the southern shore and at a group of stations in the eastern part of the lake. Diatoms remained dominant at stations on the western shore, between Hamilton and Toronto and at several offshore stations in the east central part of the lake. Microflagellate abundance was quite variable, although this group dominated several offshore stations, particularly in the eastern half of the lake. During July, blue-green algae first became relatively important in the phytoplankton assemblage, particularly at stations in the far eastern part of the lake and at certain stations along the southern shore.

Samples taken during the August cruise showed a considerable increase in the relative importance of green algal species, particularly at stations in the eastern part of the lake where they were dominant in the assemblages collected at most stations. Some increase in the relative importance of blue-green algae was also noted, although highest levels occurred at scattered stations. In October (note scale change), however, this group became dominant at many stations. They were most important at a series of stations near mid-lake, while in other areas, particularly in the eastern half of the lake, assemblage abundance was more evenly distributed among the major groups. While the green algae generally declined in relative importance in this set of samples, the diatoms again became dominant at isolated stations along the western and southern shores. Somewhat surprisingly, the dominance of blue-green algae was maintained into the November 1972 sampling period. This group was either dominant or co-dominant with the diatoms at many stations, although the latter group was significantly more abundant than any other at many nearshore stations throughout the lake. By February 1973, the blue-green algae had declined to insignificant levels at most stations sampled although a few relatively high population densities were still found. Diatoms were dominant at most stations, with relatively minor contributions from other groups. In March, diatoms were dominant at nearly all of the stations sampled, with minor contributions from the other groups. The proportion of the total phytoplankton assemblage contributed by this group was especially large at stations near shore, apparently as a result of the initiation of the spring diatom bloom. Approximately the same situation was present in the April samples (note scale change). Diatoms were dominant at all stations, with very minor contributions from the other groups. It did appear, however, that there was an increase in the importance of microflagellates relative to the other minor components of the flora.

In June there was a dramatic increase in the relative importance of microflagellates. At the time our samples were taken, this group was dominant at most offshore stations and co-dominant with diatoms at many nearshore stations. Unlike the previous two months, the other two major groups, particularly the green algae, had begun to increase and constituted a still minor but appreciable part of the total phytoplankton flora, especially at stations nearest shore.

Diversity Trends in Near-surface Waters

The Shannon-Weaver index, a gross measure of assemblage structure, was calculated for near-surface phytoplankton assemblages analyzed during the course of this investigation. Although the results of any such integrative measure should be interpreted with caution, certain interesting patterns are present in Lake Ontario. The calculated diversity of most samples taken during the May cruise (Fig. 14) was uniformly rather high, with values less than 2.0 being found only at stations 69, 71 and 85 in the east central part of the lake. Samples taken during June 1972 also showed relatively high diversities at most stations, however, values below 2.0 were found at stations 92 and 105 in Mexico Bay and at a group of stations in the south central part of the lake, including shoreward stations between Rochester and Niagara and extending out to mid-lake stations. Average diversity decreased significantly during July, and the apparent pattern of the previous month was reversed. Most stations sampled during this month had diversities less than 2.0, and higher values were restricted to a group of nearshore stations in the far western part of the lake near Hamilton and Toronto, stations 90, 92 and 105 in the Oswego-Mexico Bay region and a group of stations in the central portion of the lake extending from the north to the south shore. In August the average diversity at stations sampled again increased, and values greater than 2.0 were found at most stations. Diversity values less than 2.0 were found only at stations 12 and 14 near Niagara, a group of stations extending from 8 and 19 near Toronto out to near mid-lake, and stations 54 and 56 in the central part of the lake. In October, average diversity values were slightly depressed, and scattered values less than 2.0 were found at stations throughout the central portion of the lake and at a few stations near shore. Average diversity values remained over 2.0 in samples collected during November 1972. Significantly lower values were found at a group of stations in the northwestern sector of the lake running from the Toronto vicinity to near mid-lake, and at a group projection from stations 72 and 73 east of Rochester northward into the lake. The former pattern was quite similar to that found in the August samples. In February 1973, the only samples which had calculated diversities less than 2.0 were mid-lake stations 46 and 77 and station 60 near Rochester. In March, diversity values less than 2.0 were restricted to certain stations near the southern shore. Included in this group were stations 89, 90 and 105 in the Oswego-Mexico Bay vicinity, station 60 near Rochester, and station 30 east of Niagara. A somewhat similar case was apparent in the April samples.

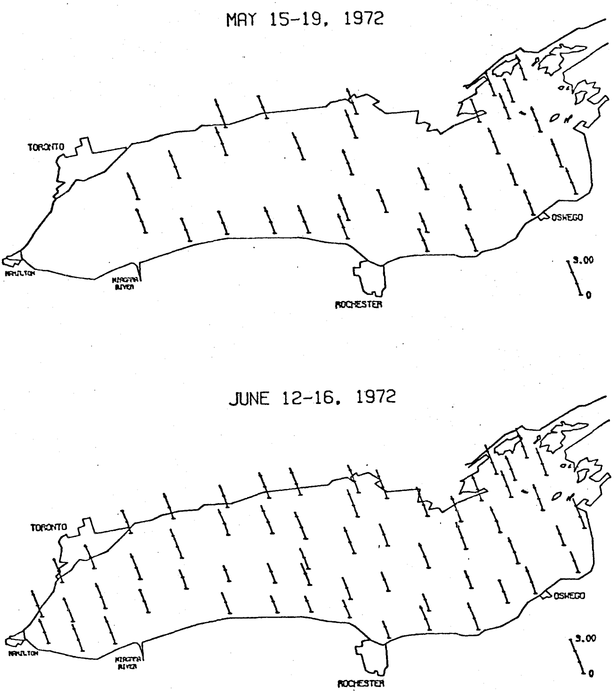


FIG. 14. Assemblage diversity (Shannon-Weaver index).

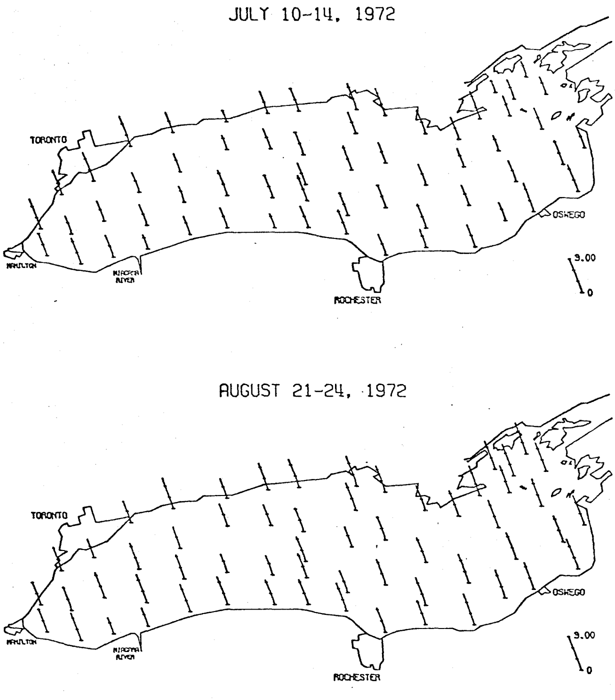
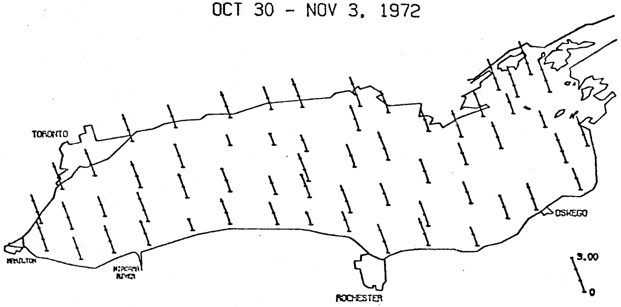


FIG. 14 continued.

OCT 30 - NOV 3, 1972



NOV 27 - DEC 1, 1972

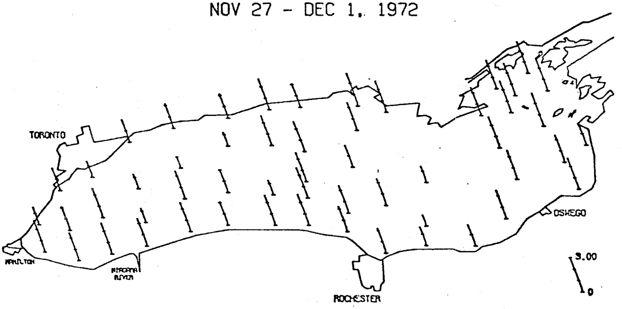


FIG. 14 continued.

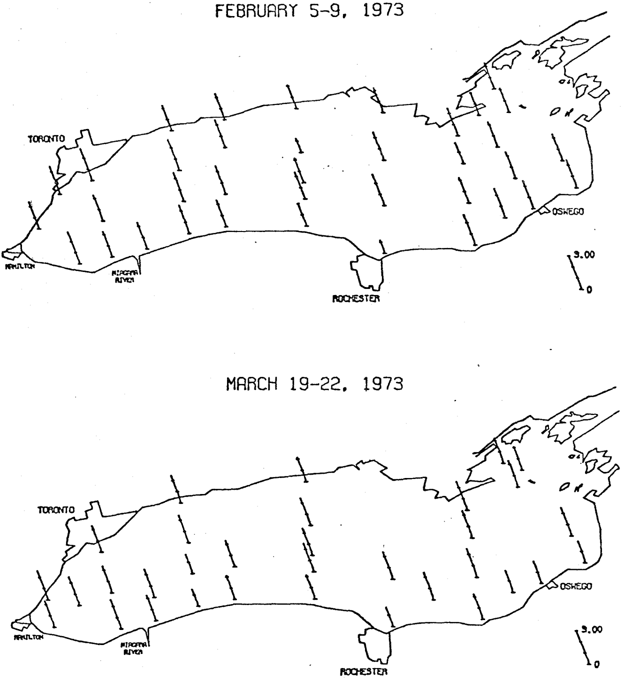
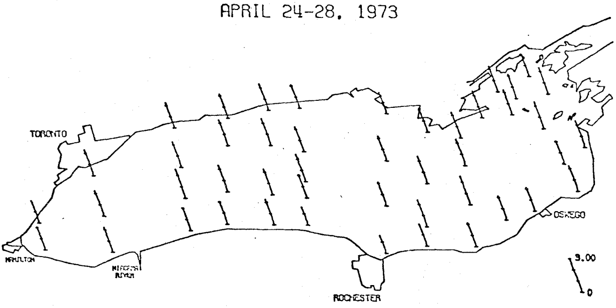


FIG. 14 continued.



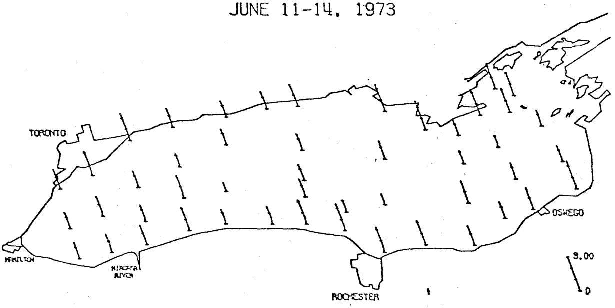


FIG. 14 continued.

The only samples from this cruise having diversities less than 2.0 were collected at nearshore stations 42, 60 and 72 in the Rochester vicinity and station 1, north of Hamilton. In June 1973 a rather dramatic reversal of the usual pattern, somewhat similar to the case found the previous July, was noted. Average assemblage diversities declined substantially, and the only samples having diversities greater than 2.0 were collected at nearshore stations, and primarily in areas which, on the basis of our other results, appear to be significantly enriched. Included in this group were stations 8 and 19 near Toronto, station 30 east of Niagara, stations 42, 59, 60 and 72 in the Rochester vicinity, station 105 in Mexico Bay, and a group of 6 stations in the northeastern part of the lake.

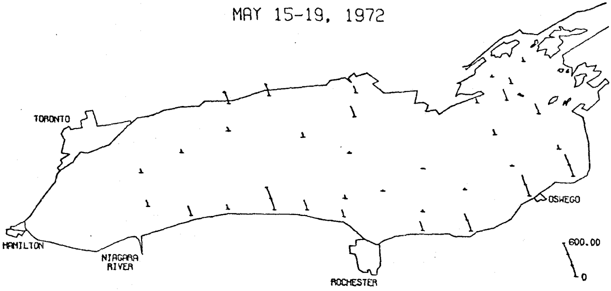
Areal Distribution of Selected Species

In the following section, data on the distribution of certain species and higher classification groups in the near-surface waters of Lake Ontario are presented. We have attempted to select those entities which are either particularly abundant in the phytoplankton assemblage or whose occurrence may be indicative of particular water quality conditions. Data are based on samples from 1 m depth. A brief discussion of the ecological affinities of the entities treated is given along with discussion of their abundance trends in Lake Ontario.

Bacillariophyta

Asterionella formosa Hass. (Fig. 15). This species is one of the most ubiquitous of all freshwater plankton diatoms. It is present in nearly all areas of the Laurentian Great Lakes. Slight morphological differences suggest that there may be strain differences in populations occurring in areas with grossly different nutrient supplies, but recent revision of the genus (Koerner 1970) retains *A. formosa* as a single species. Hohn's (1969) study of plankton diatom populations in Lake Erie suggests that this species did not drastically change in absolute abundance during the period that Lake Erie underwent drastic apparent reduction in water quality. It was, however, reduced in relative abundance. Apparently this species can tolerate considerable eutrophication and is favored by increased nutrient levels.

During the IFYGL sampling period on Lake Ontario it was present at most stations sampled throughout the year. During the May 1972 cruise, highest populations were noted at stations relatively near shore. Although still abundant in June of the same year, highest population levels were noted at mid-lake stations. Overall abundance of this species was considerably reduced by July, although fairly high counts were noted at a few offshore stations. Populations reached and remained at low levels during August and October 1972. Slight increases were noted during the November 1972 and February 1973 cruises. The earliest indication of a spring bloom of this species was considerably



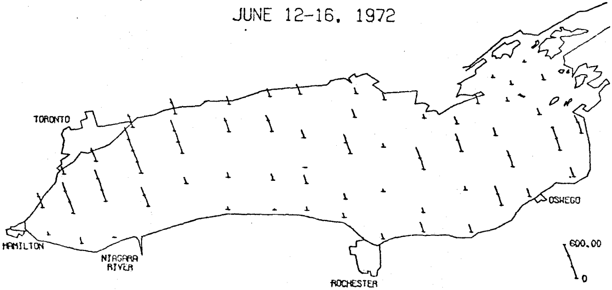
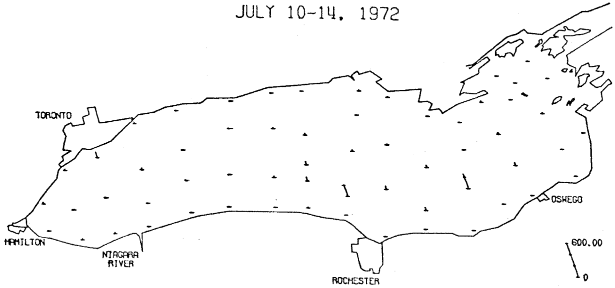


FIG. 15. Distribution of *Asterionella formosa*.



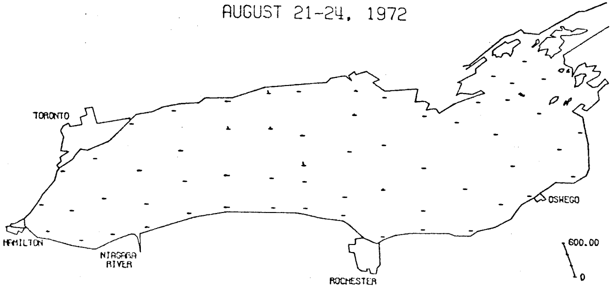
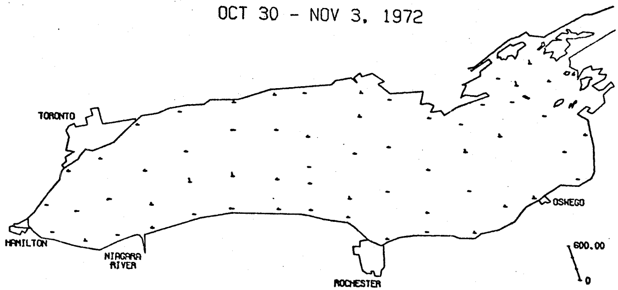


FIG. 15 continued.



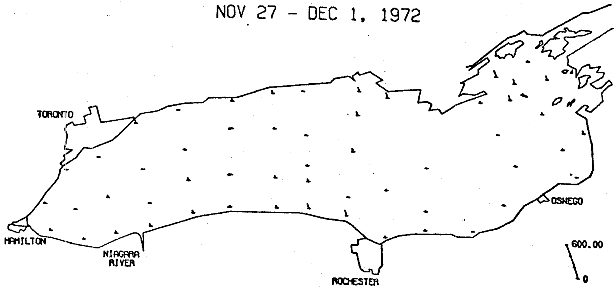
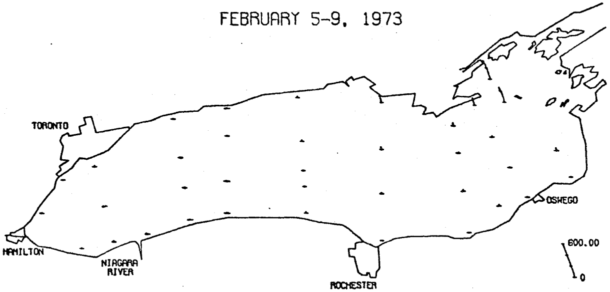


FIG. 15 continued.



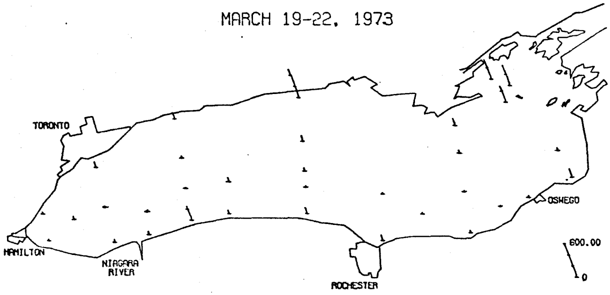
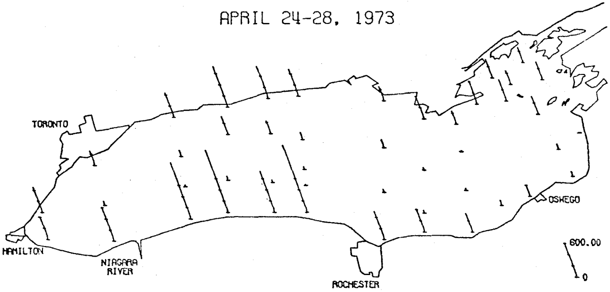


FIG. 15 continued.



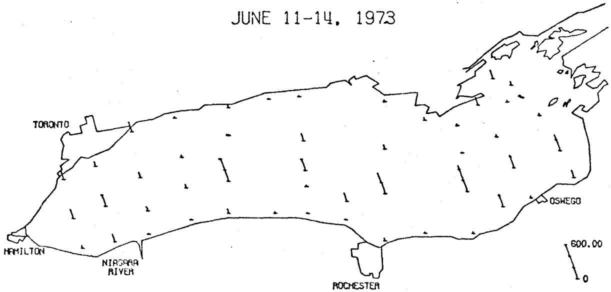


FIG. 15 continued.

elevated population densities noted at stations in Prince Edward Point area during the February sampling period. During March 1973, population densities of *A. formosa* remained high at stations in this region, and similarly elevated levels were noted at a few other nearshore stations. By the April 1973 sampling interval, very high population levels were found at most stations relatively near shore. As in the previous year, by June 1973 populations were significantly reduced at nearshore stations, although remaining high in the south central part of the lake.

Coscinodiscus subsalsa Juhl.-Dannf. (Fig. 16). If a single diatom were to be chosen as being indicative of extreme disturbance in the Laurentian Great Lakes, this species would be a prime candidate. It is apparently tolerant of extreme levels of nutrient enrichment and conservative element contamination. In Lake Erie it is one of the species which have shown the greatest increase between the 1938-1940 period and 1965 (Hohn 1969). According to Hohn's results it was exceedingly rare in Lake Erie prior to 1950. Although present in Lake Michigan, its distribution is almost entirely restricted to polluted harbors and adjacent nearshore areas (Stoermer and Yang 1969). Even in highly disturbed areas its numerical abundance is not particularly great compared to some of the other pollution-tolerant taxa, but because of its relatively large cells it contributes considerably to the biovolume of the assemblage (Hohn 1969).

Unlike most diatom species, *C. subsalsa* apparently requires relatively high temperatures for maximum growth, and population maxima usually occur in the late summer and fall. During the IFYGL sampling period on Lake Ontario this seasonal preference was quite evident. During the May 1972 cruise it was found at a single station in Mexico Bay. In the June 1972 samples it was detected at two stations, also in the eastern part of the lake. In both cases population levels were very low. In the July 1972 samples, higher populations were found at two stations in Mexico Bay and by August at all stations east of Oswego and Pt. Petre. This species was detected also at stations 72 and 73 east of Rochester and 49 and 66 in the Presqu'ile Bay - Scotch Bonnet Lt. area. The latter pattern is particularly interesting since it is repeated in the November results. Samples taken during October 1972 showed a reduction in the number of stations occupied by *C. subsalsa*, but relatively high population levels were still present at some stations in the eastern part of the lake. A similar pattern was noted in the November 1972 samples. In February 1973 this species was noted at a single station near Niagara and only at a few scattered stations, primarily in the eastern part of the lake, in March and April 1973. The only apparent consistency in these months was its occurrence at station 90 near Oswego. It was not noted in our June 1973 samples.

Diatoma tenue var. *elongatum* Lyngb. (Fig. 17). Available information suggests that this species was introduced into the waters of the

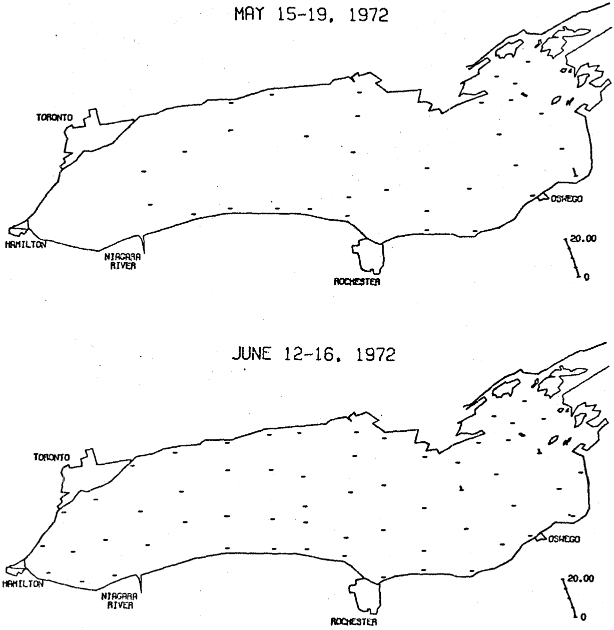
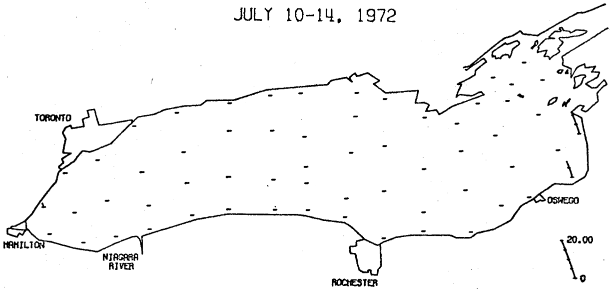


FIG. 16. Distribution of *Coscinodiscus subsalsa*.



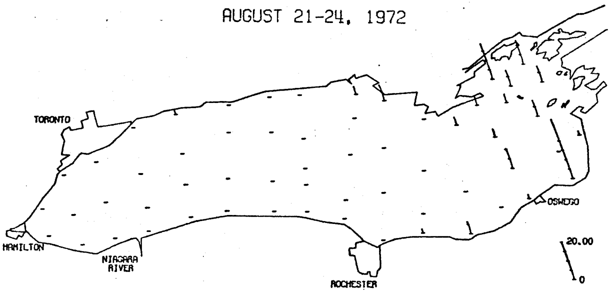


FIG. 16 continued.

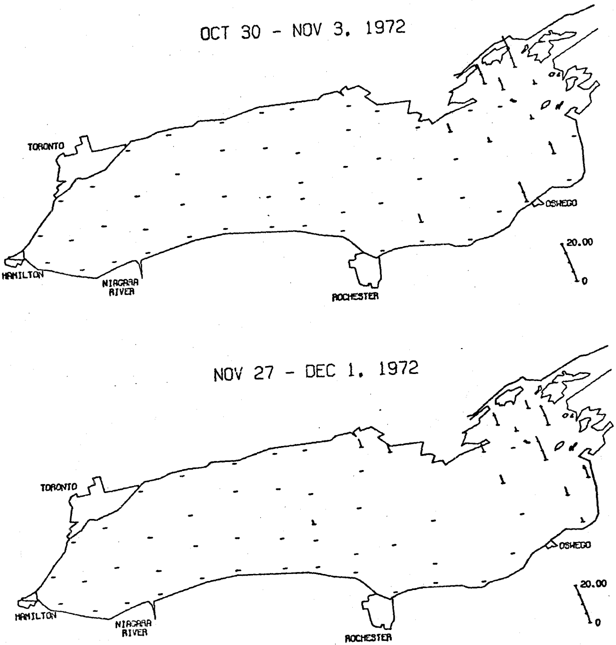
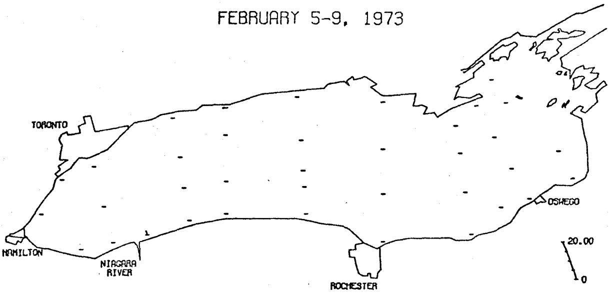


FIG. 16 continued.



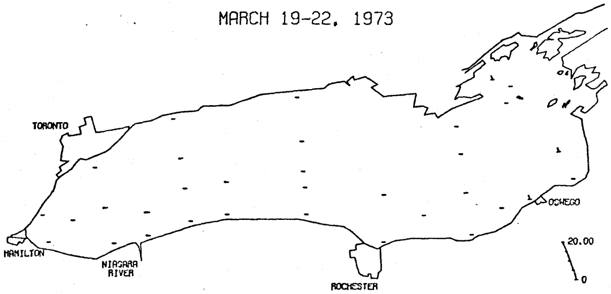
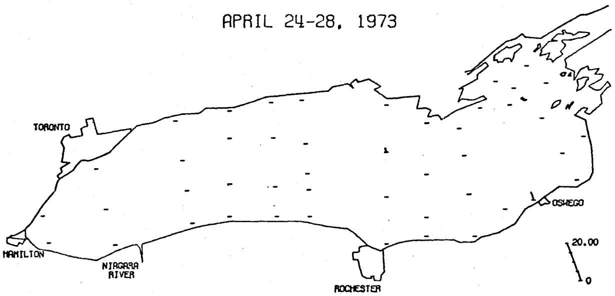


FIG. 16 continued.

APRIL 24-28, 1973



JUNE 11-14, 1973

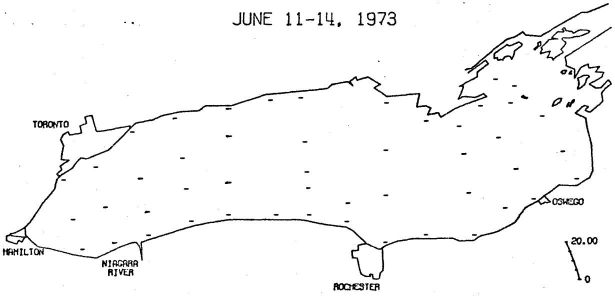


FIG. 16 continued.

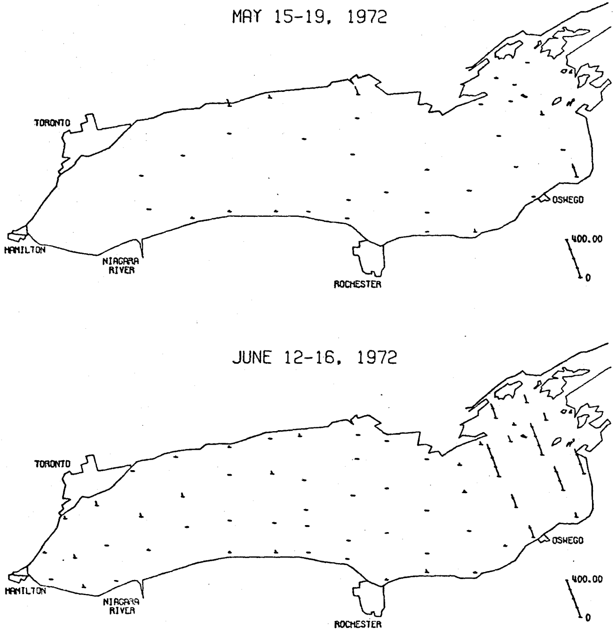
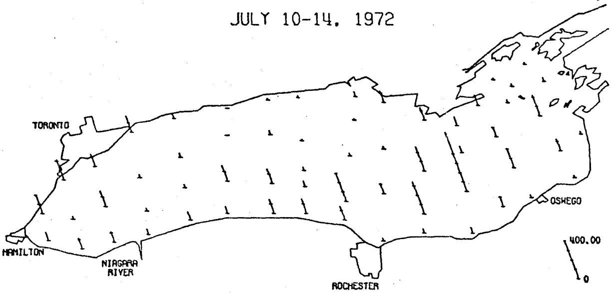


FIG. 17. Distribution of *Diatoma tenue* var. *elongatum*.

JULY 10-14, 1972



AUGUST 21-24, 1972

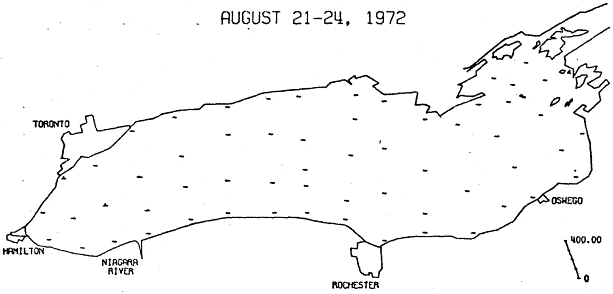
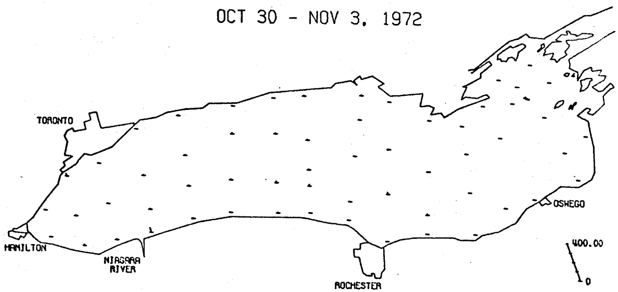


FIG. 17 continued.



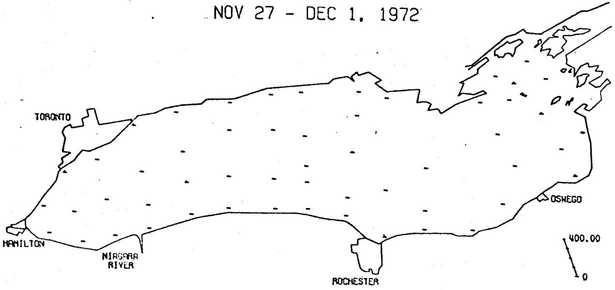
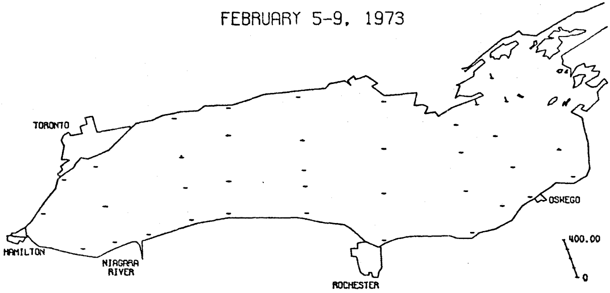


FIG. 17 continued.



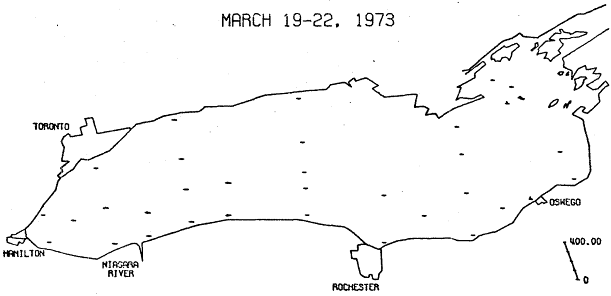
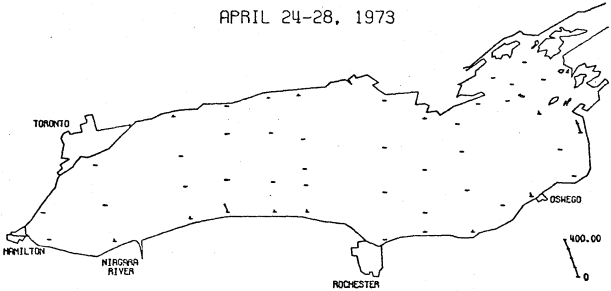


FIG. 17 continued.



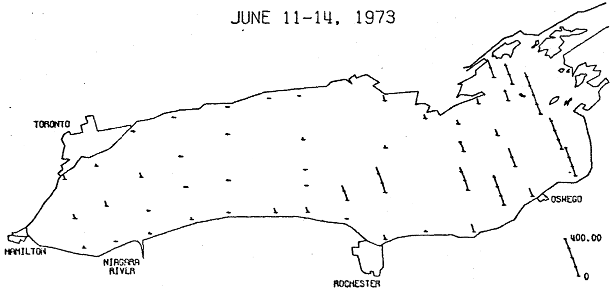


FIG. 17 continued.

Laurentian Great Lakes only after a considerable degree of disturbance had taken place. Hohn (1969) lists it among the species which were absent or only rarely noted in historic collections from Lake Erie but which has become a major dominant in the past few decades. Similarly, Stoermer and Yang (1969) did not find it in very early collections from Lake Michigan although it was present there as early as 1932 (Ahlstrom 1936) and became abundant as early as 1946. At the present time it occurs throughout Lake Michigan and is especially abundant in nearshore waters and in polluted harbors. It has been widely reported from Lake Ontario (Nalewajko 1966; Michalski 1968; Reinwand 1969; Munawar and Nauwerck 1971). Most of these authors report *D. tenue* var. *elongatum* as being particularly abundant in winter and early spring collections.

Like many species with similar patterns of occurrence in the Great Lakes, *D. tenue* var. *elongatum* appears to be favored by elevated levels of conservative ions (Huber-Pestalozzi 1942) as well as nutrient pollution.

In samples collected during our May 1972 sampling cruise, low level populations of this species were noted, particularly at nearshore stations. Population densities exceeded 100 cells/ml in only one sample, from Mexico Bay, collected during this cruise. Increased population densities were noted in collections taken during June, particularly at stations east of a line from Oswego to Point Petre. A continued increase was noted in collections taken during July, with a tendency for highest population densities to occur in the southern half of the lake. By August these populations had been considerably reduced and remained at low levels during the October and November 1972 and February and March 1973 cruises. In April 1973, one population exceeding 100 cells/ml was noted in the eastern part of the lake, and there appeared to be a general increase in the population density at nearshore stations. As had been the case the pervious year, *D. tenue* var. *elongatum* bloomed at stations in the eastern part of the lake in June 1973.

Fragilaria capucina Desm. (Fig. 18). The world distribution records of this species suggest that it is primarily a littoral species which can become important in the plankton of eutrophic lakes (Huber-Pestalozzi 1942). Hohn (1969) reports that it has become a dominant in western Lake Erie since 1950 and may comprise as much as 90% of the total phytoplankton assemblage at certain stations in the island area of that lake. According to Stoermer and Yang (1969), low level populations were present in historic collections from Lake Michigan, however abundant occurrences are largely restricted to highly eutrophied areas such as certain harbors and southern Green Bay. It has been noted as being abundant in Lake Ontario by some investigators (Nalewajko 1966; Reinwand 1969) but not reported by others. Michalski (1968) indicates it is more abundant in the Bay of Quinte than in Lake Ontario proper. Its tendency to occur in very large colonies leads to large uncertainties in estimates of its abundance made by standard plankton counting methods.

Only low population levels of this species were noted in our samples from

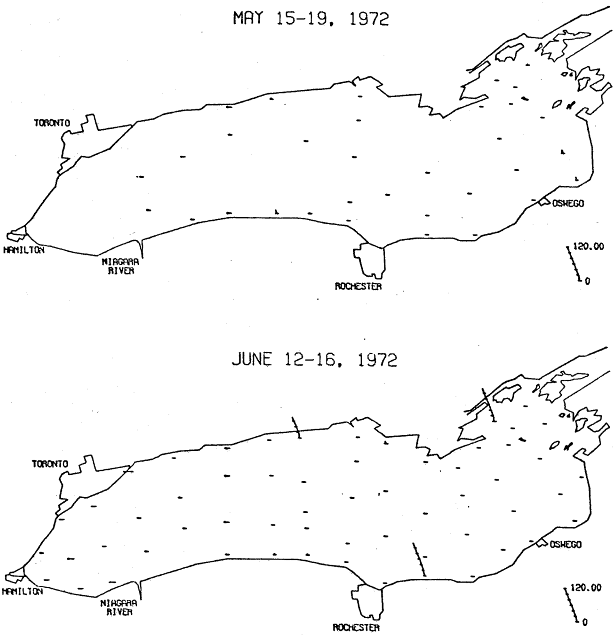


FIG. 18. Distribution of *Fragilaria capucina*.

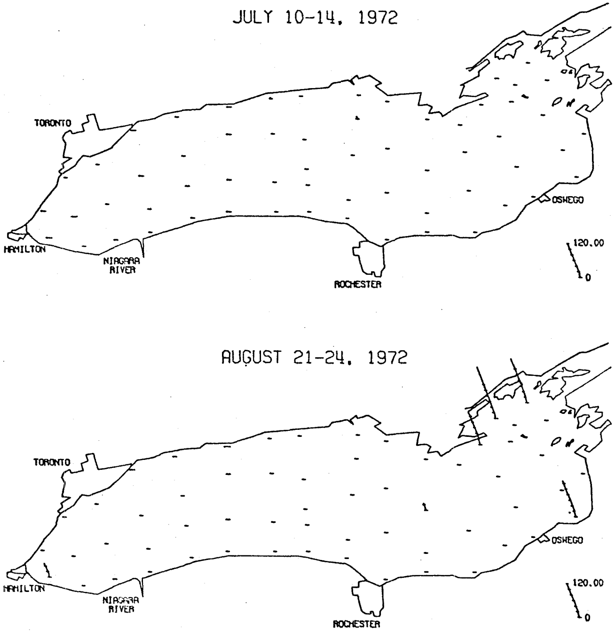
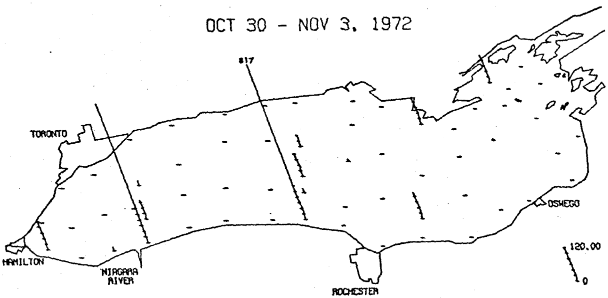


FIG. 18 continued.



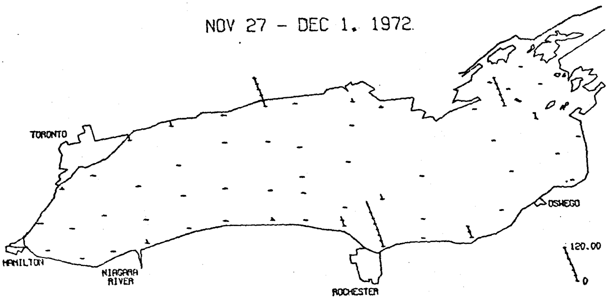
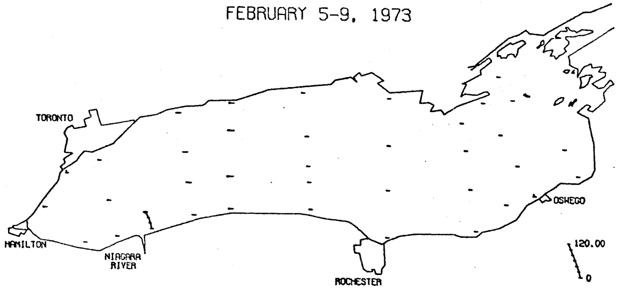


FIG. 18 continued.



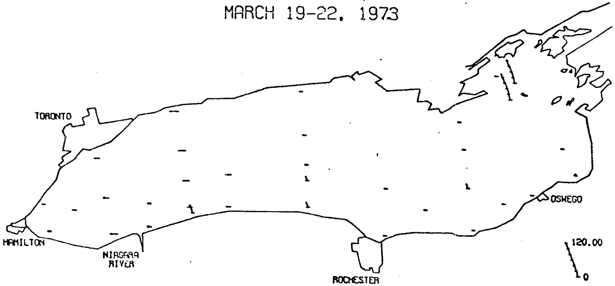


FIG. 18 continued.

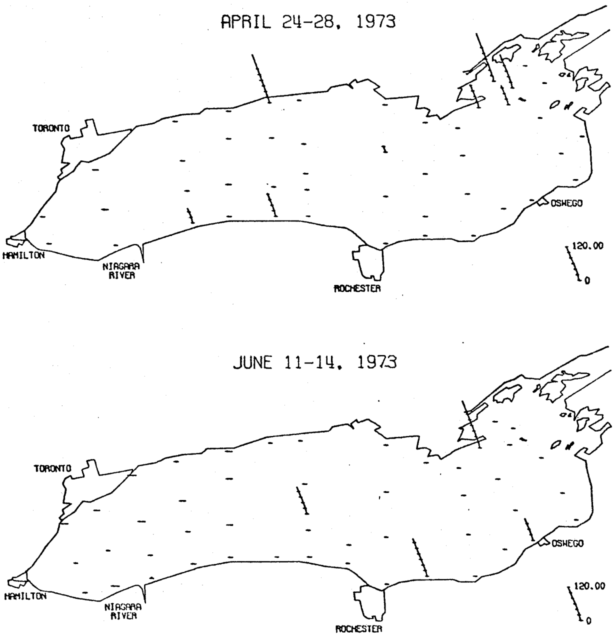


FIG. 18 continued.

the May 1972 cruise. In the June samples, high population densities were noted at a few isolated nearshore stations, although this species was not particularly abundant at most stations. The high populations noted the previous month had declined by July, and only a few low-level occurrences were noted in collections from that month. Increased population densities were noted at several stations in the eastern part of the lake and at station 2 near Hamilton during the August cruise. The greatest abundance of *F. capucina* found during the IFYGL field sampling period occurred during the October cruise, when very high populations were found at two stations near the southern shore and relatively high population densities were noted at several offshore stations. In samples from the November 1972 cruise, high population densities were again restricted primarily to stations nearest shore, and by February 1973 *F. capucina* was noted only at station 14 near Niagara and station 90 near Oswego. In our samples from March 1973, high population densities were noted at stations 79 and 96 in the eastern part of the lake and minor increases at several other stations. Further increases, again primarily at stations nearest shore, were noted in samples from the April cruise. In June the number of stations having high population densities of *F. capucina* decreased, but one abundant occurrence was noted off shore at station 45.

Fragilaria crotonensis Kitton. (Fig. 19). This species is one of the most common and widely distributed of all freshwater plankton diatoms. It is apparently able to tolerate a wide range of ecological conditions, and populations are found in nearly all areas of the Laruentian Great Lakes. Some evidence of its adaptability is apparent in Hohn's (1969) finding that it was one of the species whose absolute abundance had not changed appreciably in western Lake Erie over the past several decades. Stoermer and Yang (1969) have speculated that its apparently wide range of tolerance may be due to the fact that several races or cryptospecies are included in the commonly accepted concept of the species, but firm evidence for this is lacking.

This species was abundant at several stations in the eastern part of the lake and some nearshore stations, particularly on the northern shore, on the basis of samples taken during the May 1972 cruise. Some general increase in population density was noted during June, again particularly in the northern half of the lake. Apparently these populations were reduced by July, and significant populations were found only at a few mid-lake stations and two stations in the western end of the lake. In August, however, population densities apparently increased again, and significant populations were found at most stations throughout the lake. Population levels were reduced in samples obtained during October and November 1973, although *F. crotonensis* remained widely distributed in Lake Ontario. This reduction in population density apparently continued, since only a few low-level populations were found in the February 1973 samples. Samples taken during March showed slight increases at a few stations relatively near shore, and by April significant populations were again present at stations in the eastern part of the lake

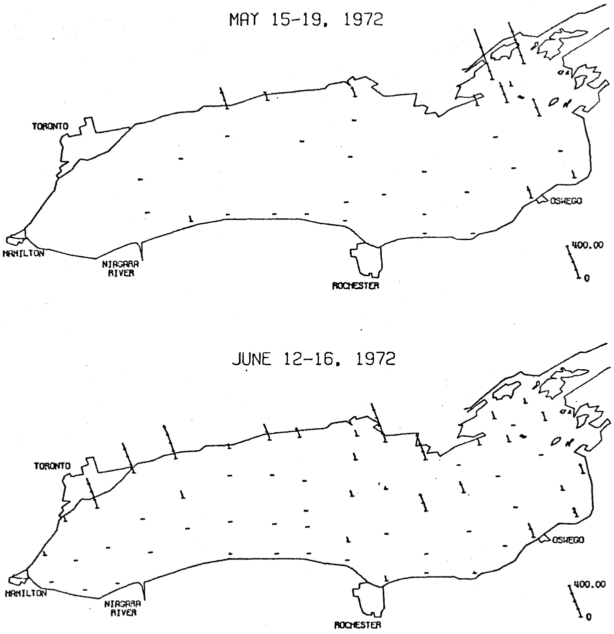
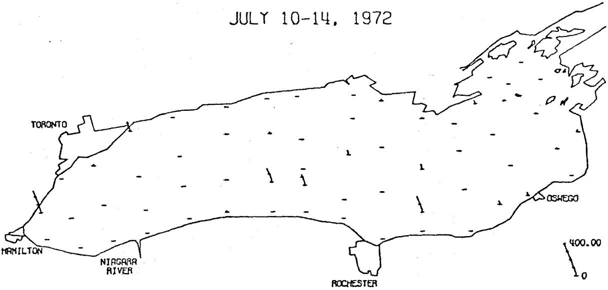


FIG. 19. Distribution of *Fragilaria crotonensis*.



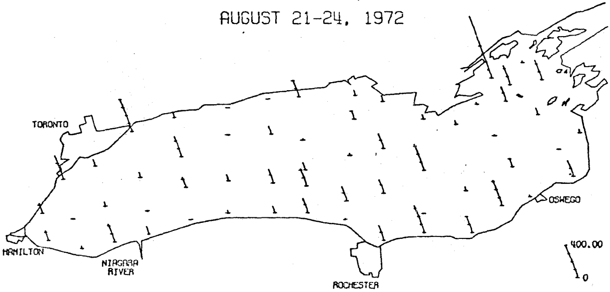
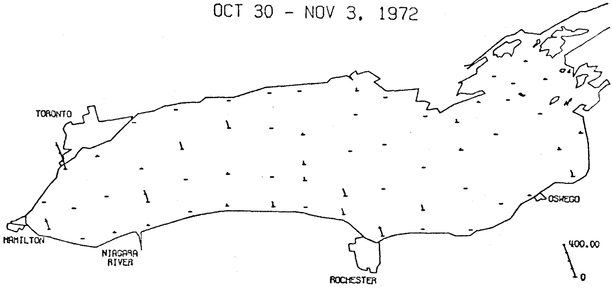


FIG. 19 continued.



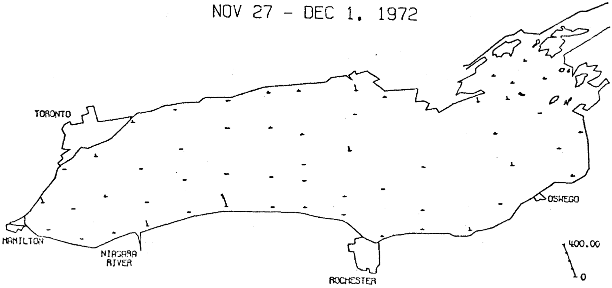
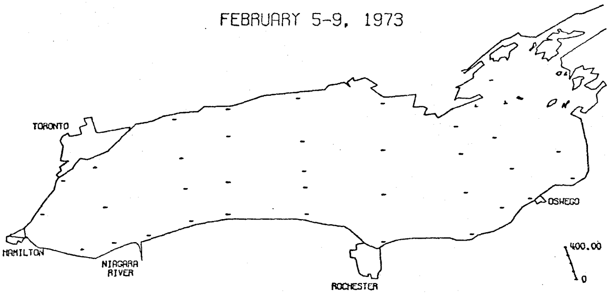


FIG. 19 continued.



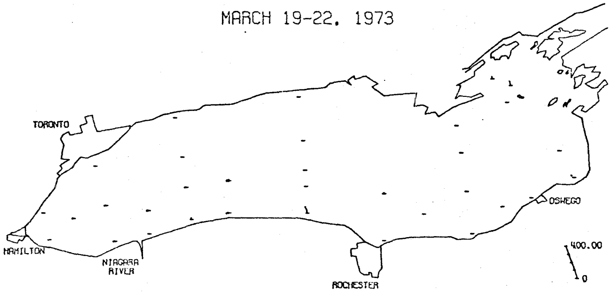
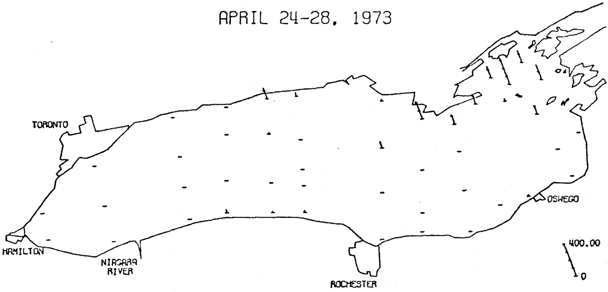


FIG. 19 continued.

APRIL 24-28, 1973



JUNE 11-14, 1973

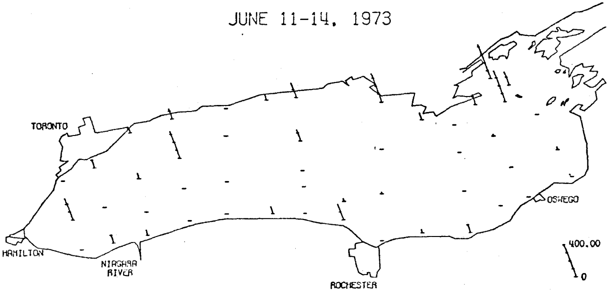


FIG. 19 continued.

and along the north shore. High levels of *F. crotonensis* were noted at numerous stations in the June 1973 samples, as in the previous year.

Melosira islandica O. Müll. (Fig. 20). This species is a common dominant in large temperate lakes. Although it is apparently not tolerent of high degrees of eutrophication, it is abundant in most areas of the Laurentian Great Lakes. Hohn (1969) indicates that it is not present in abundance in Lake Erie, and Holland (1968) has shown it is much less abundant in highly eutrophic regions of Green Bay than it is in the offshore waters of Lake Michigan. Nalewajko (1966) found it to be relatively much more abundant in collections from offshore stations in Lake Ontario than it was in nearshore stations. Most literature sources indicate that *M. islandica* reaches its maximum abundance at water temperatures less than 12°C, and Munawar and Nauwerck (1971) found it to be a spring dominant in Lake Ontario.

Sizable populations were present in most of our samples from May 1972, although there was a tendency for lower populations to be present at mid-lake stations. The highest population densities noted during our study were found in the June 1972 samples. At this time most stations sampled had significant populations of *M. islandica* but there was a tendency toward reduced population densities at stations near the American shore, particularly in the Rochester vicinity. By July, populations had been strikingly reduced, and this situation continued through the August, October and November sampling period. Slightly increased abundance was noted at some inshore stations sampled in February, and the beginning of the spring bloom period was visible in our March results. In 1973, highest population densities were found in the April samples, although there was still a clear difference in abundance between the mid-lake and shoreward areas at the time the samples were taken. In striking contrast to the previous year's samples, populations of this species had collapsed at all but a few mid-lake stations by June 1973.

Nitzschia bacata Hust. (Fig. 21). Although the reported distribution of this species is primarily restricted to large, tropical lakes (Hustedt 1949), populations occurring in the Laurentian Great Lakes appear to be morphologically identical to typical populations. Although Stoermer and Yang (1969) have recorded this entity from a number of localities in Lake Michigan, other reports from the Great Lakes are lacking. So far as previous reports from Lake Ontario are concerned, we suspect that this species has been included under *N. acicularis* which it somewhat resembles, and perhaps *Synedra* spp. which are exceedingly difficult to distinguish from planktonic *Nitzschias* in settled preparations.

In our collections this species was relatively abundant at nearshore stations sampled during May 1972, and smaller populations occurred at most offshore stations. It apparently continued to increase in abundance at

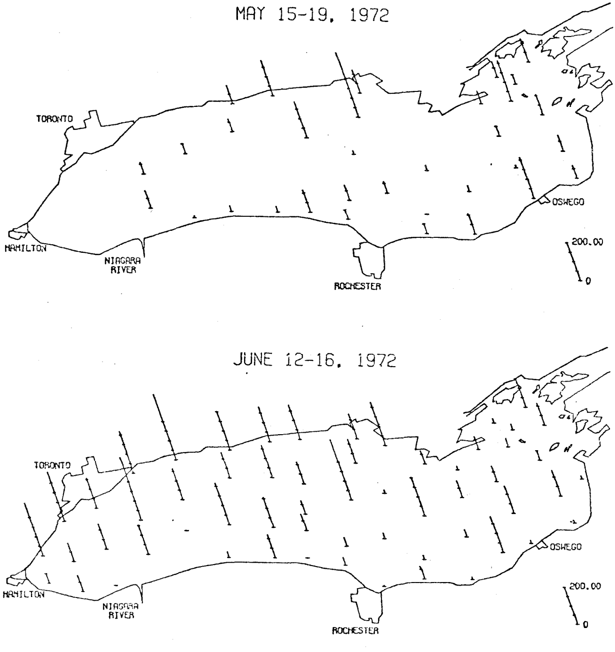


FIG. 20. Distribution of *Melosira islandica*.

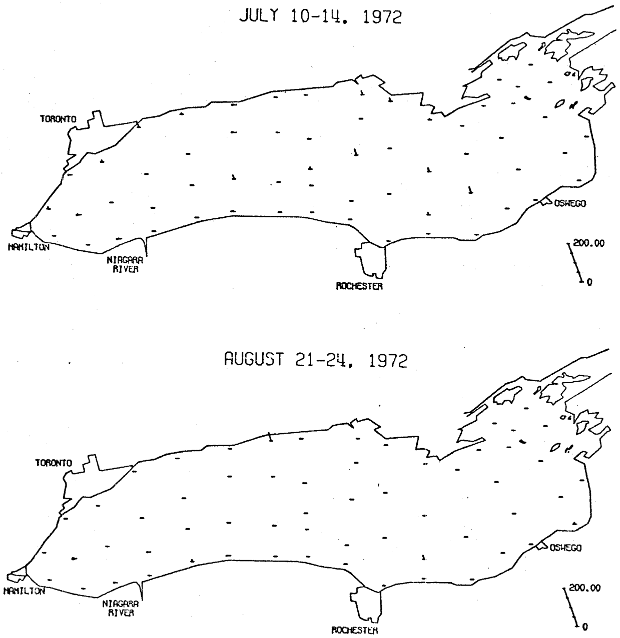
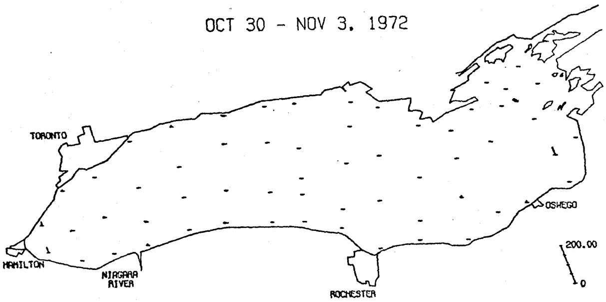


FIG. 20 continued.



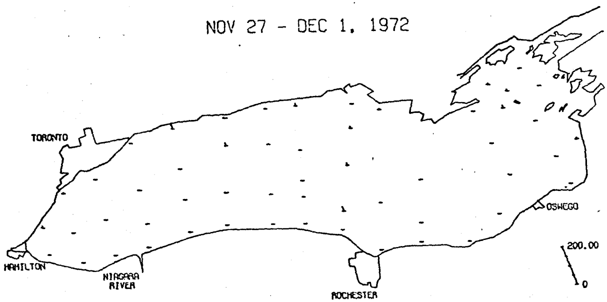
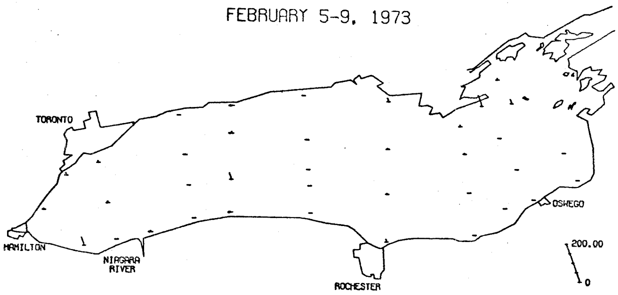


FIG. 20 continued.



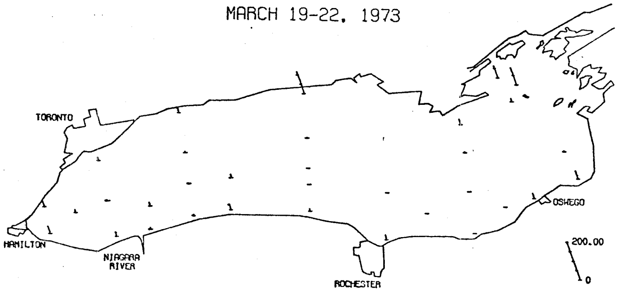
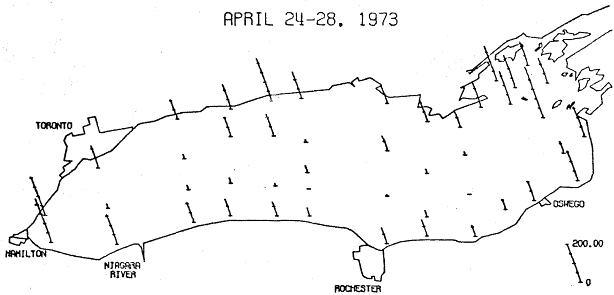


FIG. 20 continued.



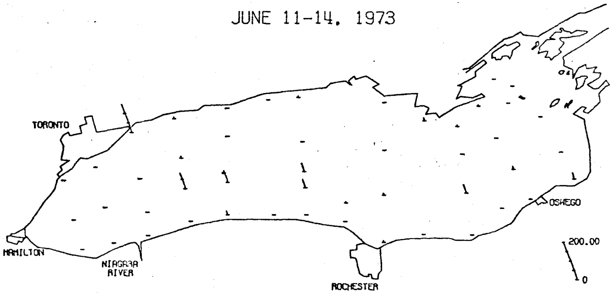
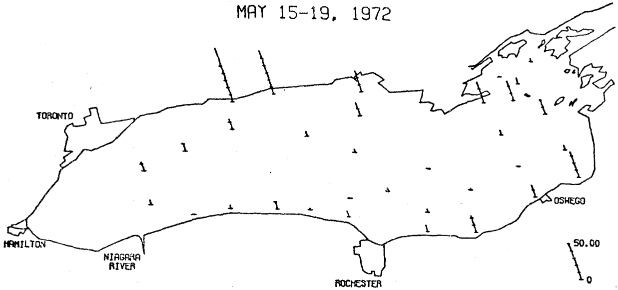


FIG. 20 continued.



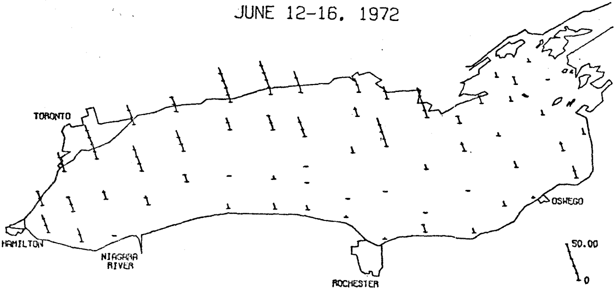


FIG. 21. Distribution of *Nitzschia bacata*.

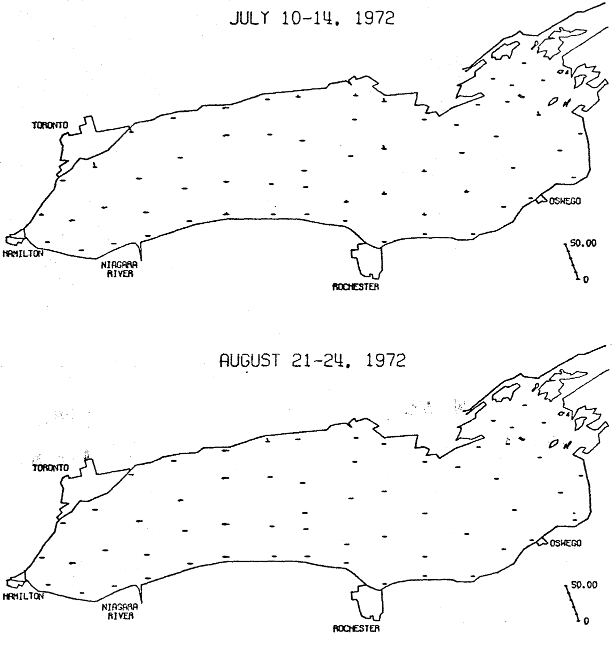
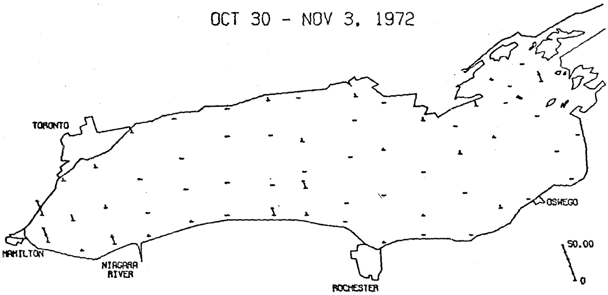


FIG. 21 continued.



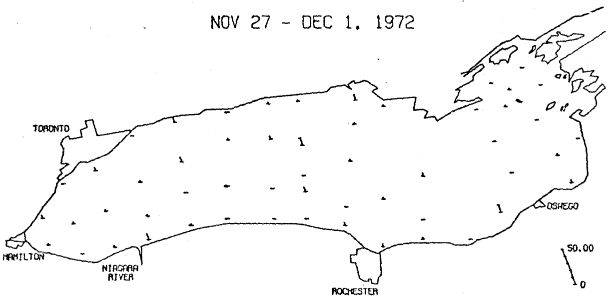
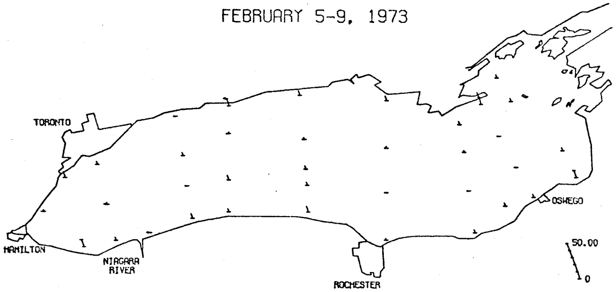


FIG. 21 continued.



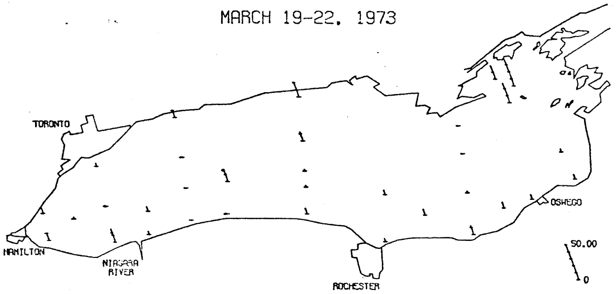
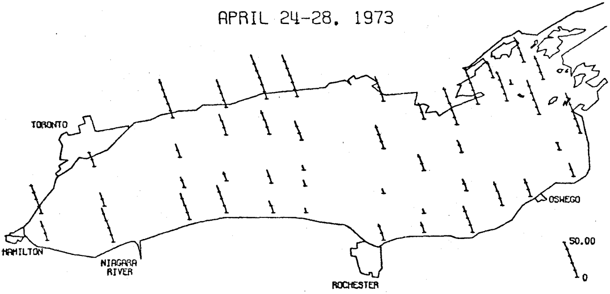


FIG. 21 continued.



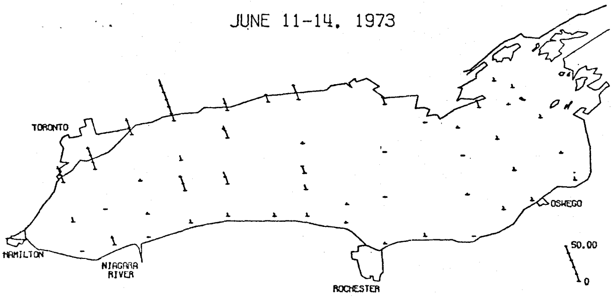


FIG. 21 continued.

most stations sampled during the June cruise, and populations were present at most stations except a series off shore in the southern half of the lake. This particular pattern was seen in several other species. By July, populations had drastically declined and only low-level populations were noted at scattered stations. This trend continued into August, when occurrences of this species were very scarce. Abundance of *N. bacata* increased again in October, particularly in the far western end of the lake, and scattered occurrences were noted in samples taken during 1972 and February 1973. In March, population densities increased markedly at a few stations in the eastern end of the lake, and there was a slight tendency toward higher numbers at stations throughout the lake. Populations peaked at stations throughout the lake in April 1973, but began to decline again, particularly at stations in the eastern half of the lake, in June.

Nitzschia dissipata (Kütz.) Grun. (Fig. 22). One of the most common and widely distributed members of the genus, *N. dissipata*, seems to be particularly abundant in the phytoplankton of the Laurentian Great Lakes. Although usually considered to be primarily a benthic rather than a planktonic species (Huber-Pestalozzi 1942), it was reported as a major species in some localities in western Lake Erie (Hohn 1969) and is apparently widely distributed in Lake Michigan (Stoermer and Yang 1969). According to Stoermer and Yang's study it was not noted in collections taken prior to 1937. Its wide distribution in the offshore waters of the Great Lakes is somewhat surprising, since some authorities consider it to be primarily a species of eutrophic habitats, and high population densities to be indicative of organic pollution (Cholnoky 1968). It has previously been reported as being common in certain localities in Lake Ontario (Nalewajko 1966; Reinwand 1969).

Although never among the major dominants in our collections, this species is rather consistently present and displays a distinct seasonal pattern. It was present in relatively high numbers in collections taken during May 1972, and slightly reduced in samples taken during the June cruise although it was still present at the majority of the stations sampled. In July, the abundance of *N. dissipata* was severely reduced and occurrences were largely restricted to stations nearest shore. This trend continued during August, with only one significant population, at station 60 near Rochester, and a few isolated occurrences at nearshore stations. Somewhat increased numbers were noted in samples taken during October, and populations were noted at several offshore stations although highest abundance was still restricted to nearshore stations. Approximately the same pattern continued during the time period covered by the November 1972 and February 1973 cruises, but there appeared to be less difference in population density of this species near shore compared to mid-lake stations. A distinct increase in the abundance of *N. dissipata* was noted in collections taken during March, and this trend apparently continued into April. By the time stations were sampled in June, populations appeared to be on the wane again and population densities were, in general, lower than they had been the previous year.

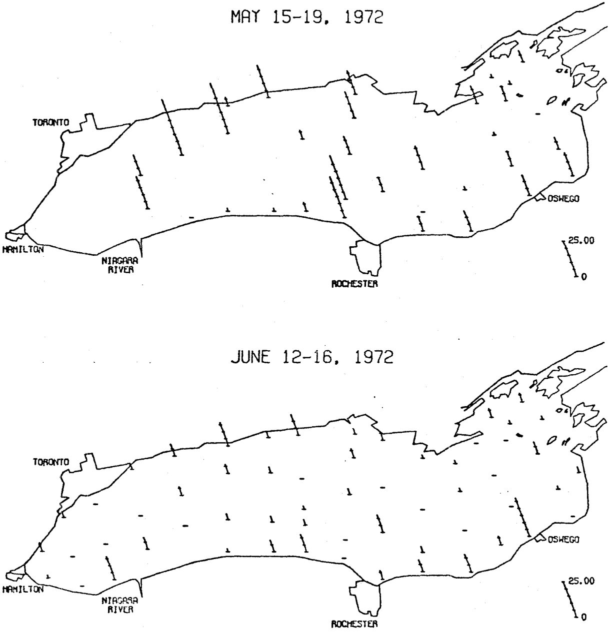
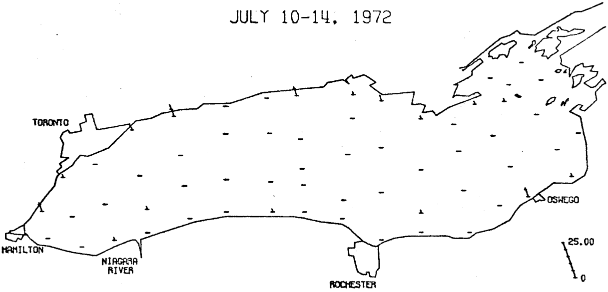


FIG. 22. Distribution of *Nitzschia dissipata*.



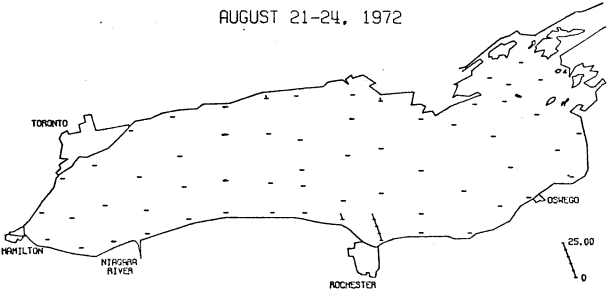
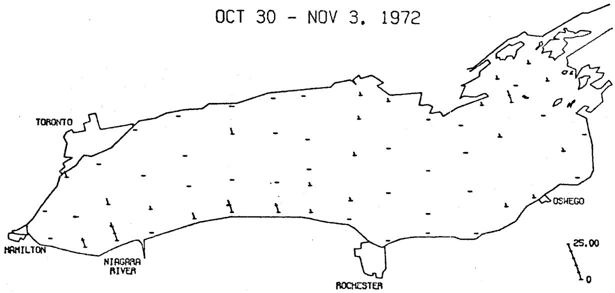


FIG. 22 continued.



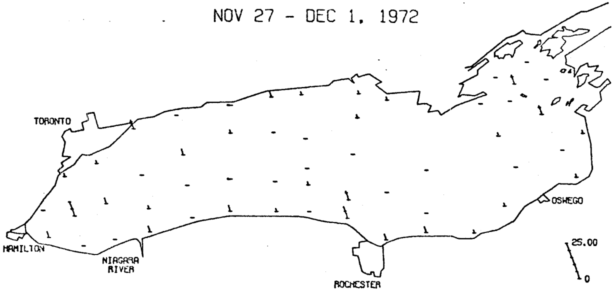
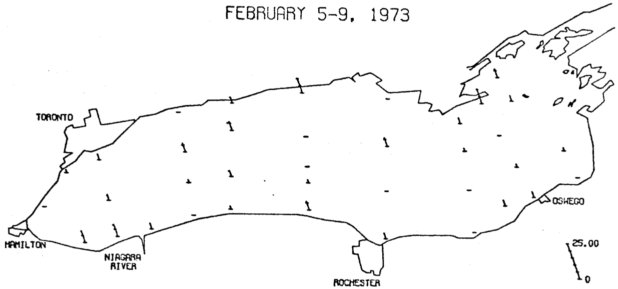


FIG. 22 continued.



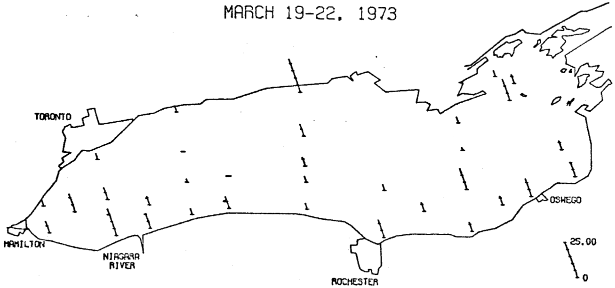
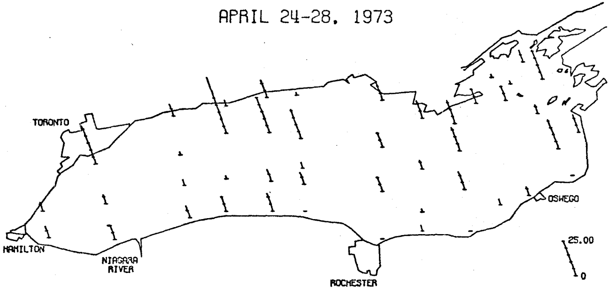


FIG. 22 continued.



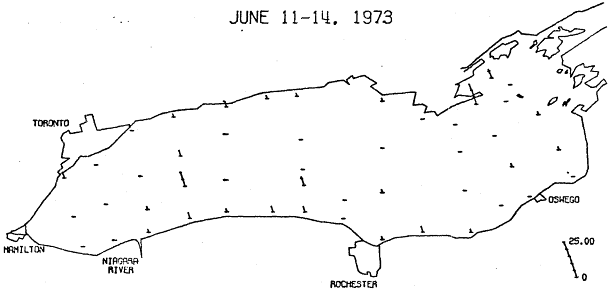


FIG. 22 continued.

Nitzschia sp. (#2) (Fig. 23). This unidentified species of *Nitzschia*, although never particularly abundant, is apparently widely distributed in the phytoplankton of the Great Lakes. Stoermer and Yang (1969) have recorded it from a variety of localities in Lake Michigan and our observations indicate that it is also present in the other lakes. It somewhat resembles *N. linearis* Wm. Smith, and some records of *N. linearis* from the offshore waters of the lake may refer to the entity we treat here. Despite its consistently low levels of absolute abundance, the distribution of this species appears to be quite uniform and, because of its relatively large size, it probably makes an appreciable contribution to the biomass of the sparse winter phytoplankton in Lake Ontario.

A number of populations of this species were noted in collections taken during the May 1972 cruise. Population densities decreased somewhat in our June samples, and there appeared to be a trend of higher population densities in the western part of the lake. Only isolated low-level occurrences were found in the July and August samples. Occurrences were noted at a larger number of stations sampled during August although population densities remained relatively low. Increased population densities were noted at a number of stations sampled during November 1972, and this trend was apparently continued in February 1973 despite the pronounced minimum in total phytoplankton density which occurred this month. Further increases in the abundance of this species were noted at most stations sampled on the March cruise, and the highest population densities found at any time during the IFYGL sampling period occurred at stations taken during the April 1973 cruise. The extremely high population densities noted the previous month had apparently been substantially reduced by the time the June 1973 samples were taken, however significant populations of this species were still present at a number of stations.

Stephanodiscus alpinus Hust. (Fig. 24). The ecological affinities of this species are difficult to determine because of the taxonomic confusion which surrounds it. It is apparently often confused with *S. astraea* and its varieties and to a certain extent with smaller species such as *S. tenuis*. According to Hohn (1969) it is one of the species which have undergone dramatic increase in Lake Erie in recent decades. According to Stoermer and Yang (1969) it has been present in Lake Michigan since the 1880's and has not enjoyed any great increase in abundance during the period of record. Their results indicate that it is primarily a winter form in Lake Michigan. Previous records from Lake Ontario are lacking.

Isolated populations of *S. alpinus* were noted in collections taken during the May 1972 cruise, particularly at mid-lake stations. Populations apparently declined by June and remained low during July and August. Populations began to increase again in October. After a slight apparent decrease in November, population densities of *S. alpinus* increased again in February 1973 and reached their highest levels in

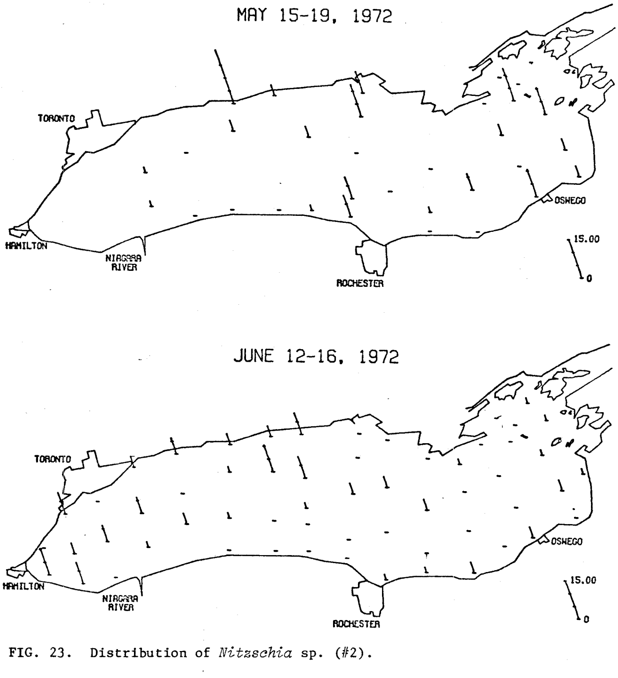
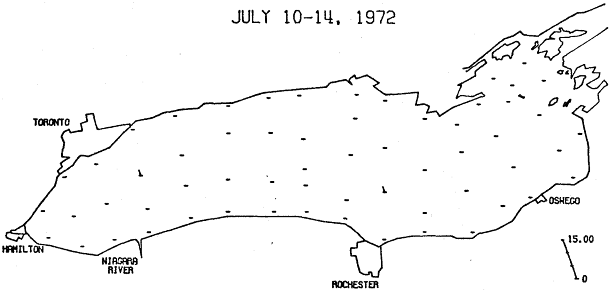


FIG. 23. Distribution of *Nitzschia* sp. (#2).



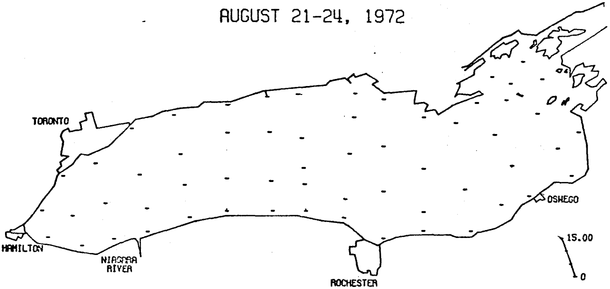
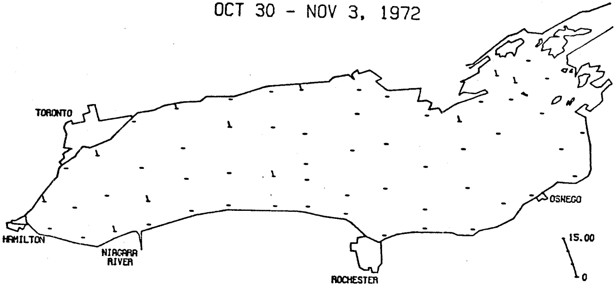


FIG. 23 continued.



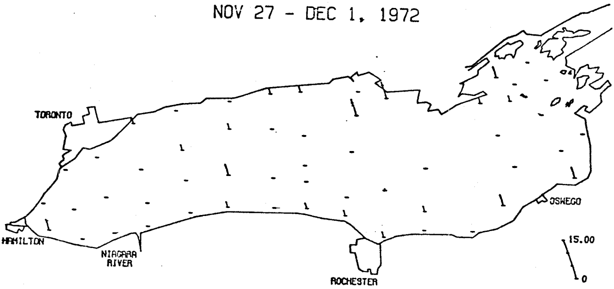
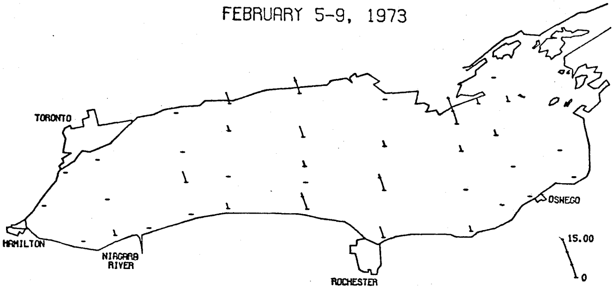


FIG. 23 continued.



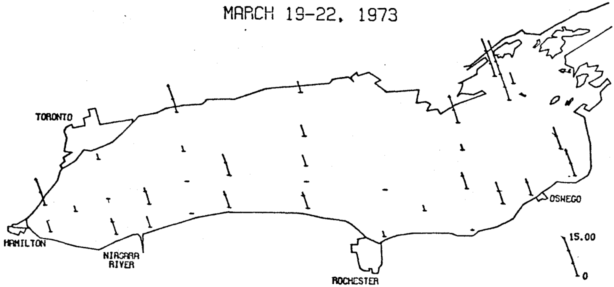


FIG. 23 continued.

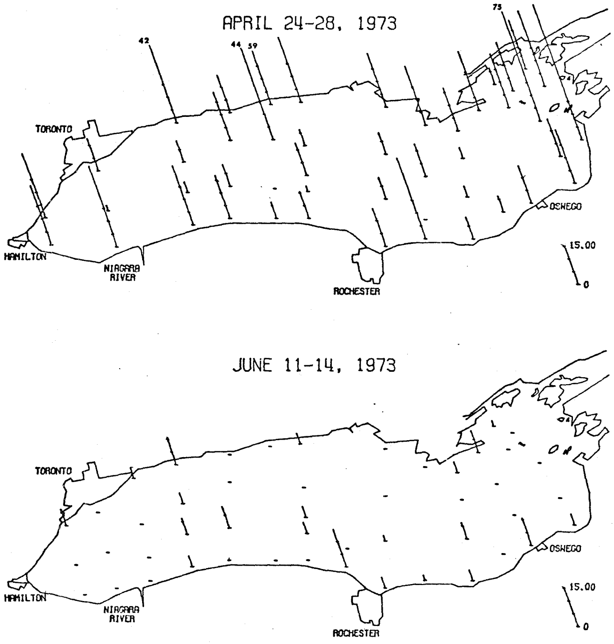


FIG. 23 continued.

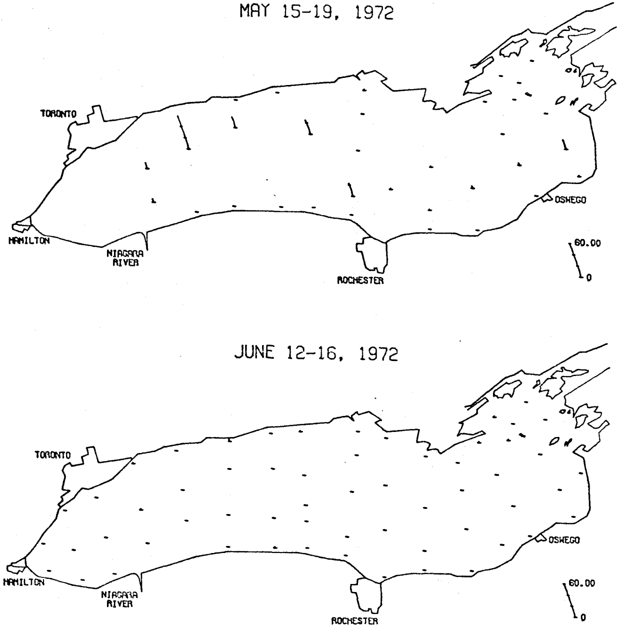
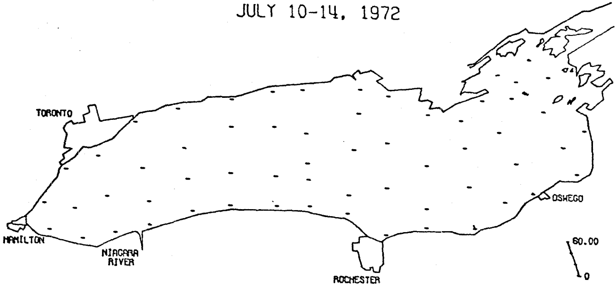


FIG. 24. Distribution of *Stephanodiscus alpinus*.

JULY 10-14, 1972



AUGUST 21-24, 1972

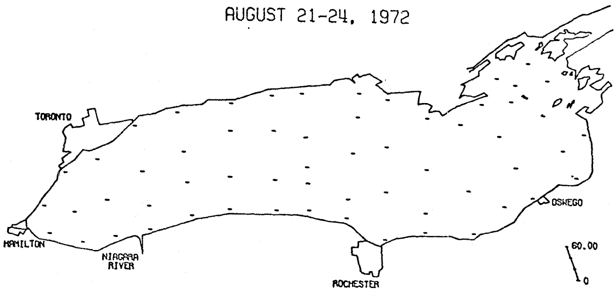
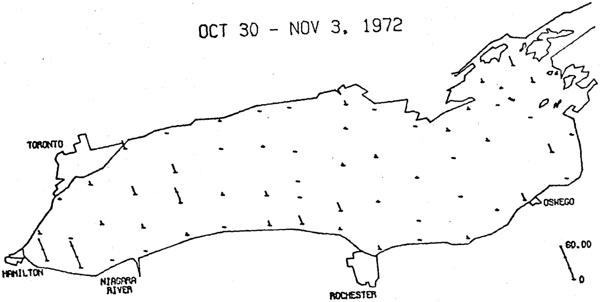


FIG. 24 continued.

OCT 30 - NOV 3, 1972



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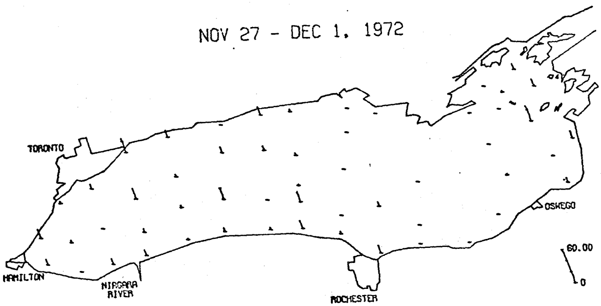
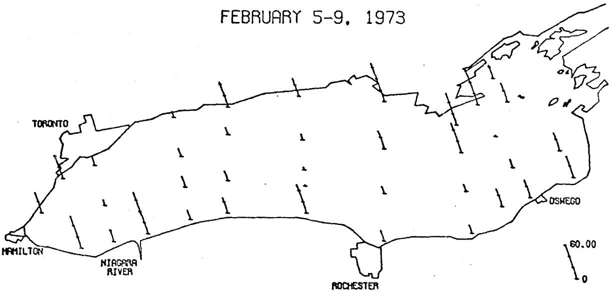


FIG. 24 continued.



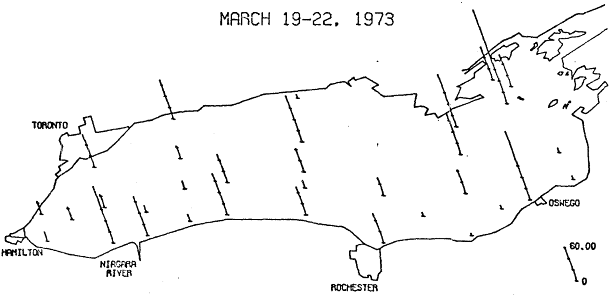
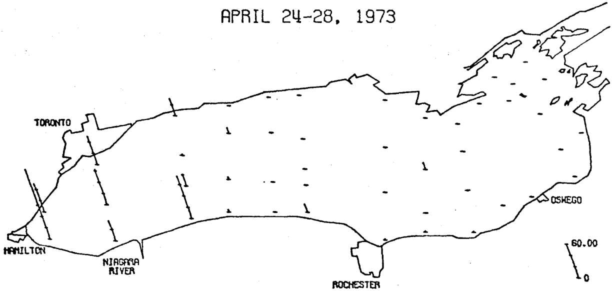


FIG. 24 continued.



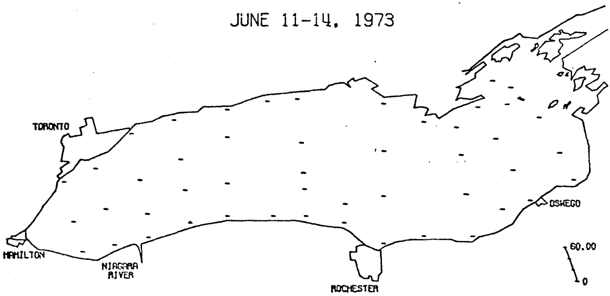


FIG. 24 continued.

samples taken during March. In April, population densities declined drastically except at a few stations in the western part of the lake, and by June this species was essentially absent. *S. alpinus* is, thus, one of the few taxa present in Lake Ontario which shows a consistent increase in absolute abundance during the winter months.

Stephanodiscus binderanus (Kütz.) Krieg. (Fig. 25). The presence of significant quantities of this species is considered to be indicative of degraded water quality conditions in the Laurentian Great Lakes. Hohn (1969) indicates that it increased greatly in abundance in Lake Erie between 1940 and 1965. In Lake Michigan it has caused significant problems at municipal water plants (Vaughn 1961), primarily in the late winter and early spring. According to Stoermer and Yang (1969), *S. binderanus* is not indigenous to Lake Michigan but is now present in the nearshore waters in considerable abundance during the spring and maintains populations in polluted harbors year-round. Most recent studies of Lake Ontario phytoplankton indicate that it has been abundant in recent years. It is difficult to arrive at a clear picture of recent and, particularly, historic trends because of the taxonomic confusion which surrounds most of the smaller species of *Stephanodiscus*.

Like many of the phytoplankton species which have invaded the Great Lakes, *S. binderanus* appears to be favored by both eutrophic conditions and considerable conservative element contamination (Huber-Pestalozzi 1942). Some authorities (Cholnoky 1968) consider it to be primarily a brackish water form. Our records indicate that its optimum temperature for growth is around 9°C, and most world distribution records indicate that it occurs in maximum abundance in the spring and fall.

During the IFYGL sampling period on Lake Ontario, *S. binderanus* was relatively abundant in samples taken from nearshore stations and stations in the far eastern part of the lake during the April 1972 cruise. At this time it was either present in only low abundance or entirely absent from mid-lake stations. In samples taken during June 1972, abundance declined somewhat in the Rochester-Oswego area and in the far eastern part of the lake, but very high population densities were noted at nearshore stations in the northwestern part of the lake and at several offshore stations. As was the case with several other species, low abundance was noted at a group of stations offshore in the southern part of the lake. By the time of the July cruise, the high population densities noted the previous month had collapsed, although low densities of *S. binderanus* were still found at most stations sampled. Only very low abundance of this species was noted at stations during August. Slight increases were found during the fall cruises, particularly at stations in the far eastern part of the lake and at certain nearshore stations closest to major cities. Population densities remained low in samples taken during February and March 1973, but increased significantly in April. A continued increase was noted in samples taken during June 1973, but populations at no time approached the densities reached the previous spring.

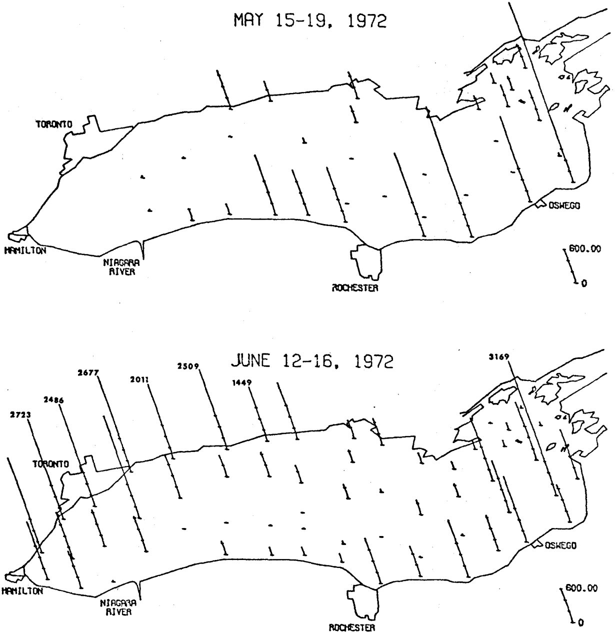
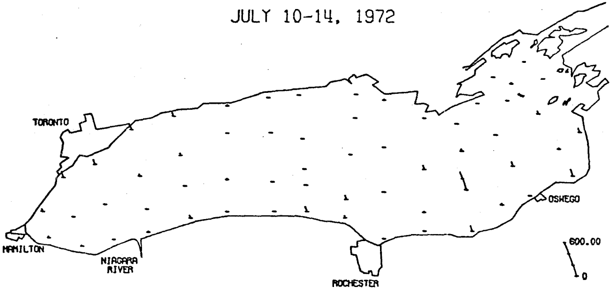


FIG. 25. Distribution of *Stephanodiscus binderanus*.



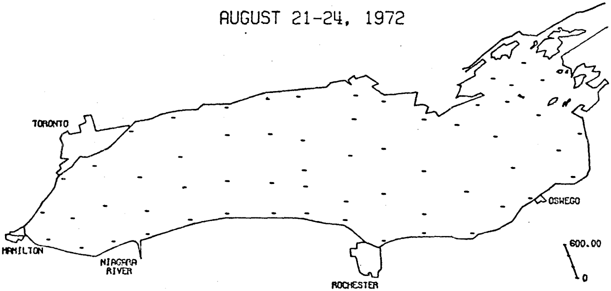
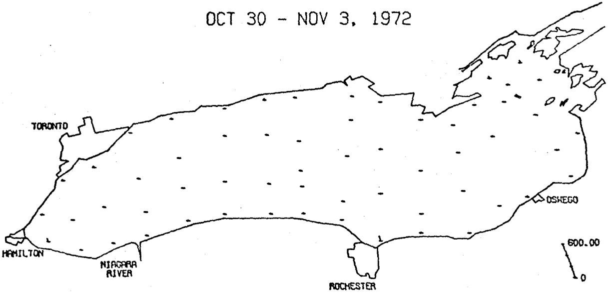


FIG. 25 continued.



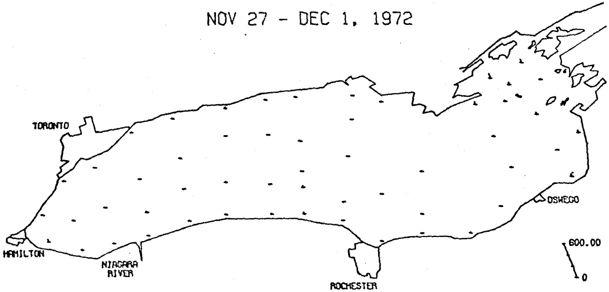
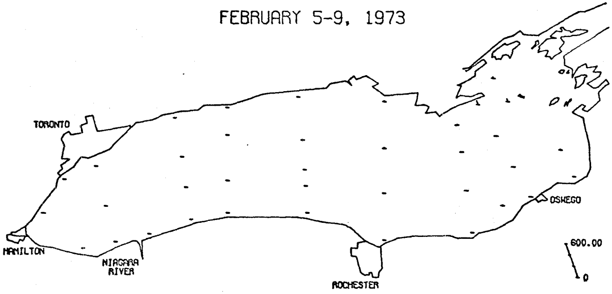


FIG. 25 continued.



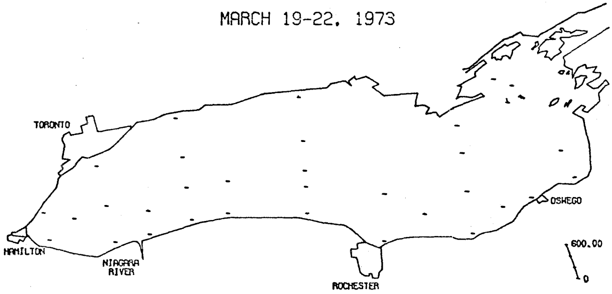
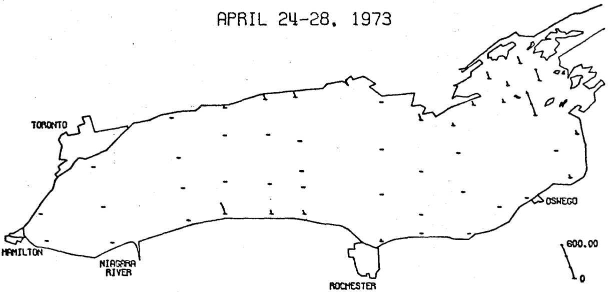


FIG. 25 continued.



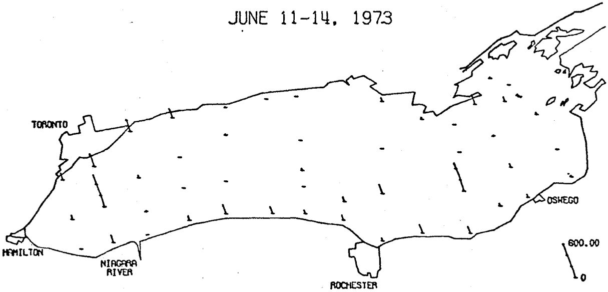


FIG. 25 continued.

Stephanodiscus hantzschii Grun. (Fig. 26). This species has long been considered a "form characteristic of strongly eutrophied waters" (Huber-Pestalozzi 1942), and in the classical European literature it has been associated with water quality degradation in large, alpine lakes (Hustedt 1930). Like several other small species of *Stephanodiscus* which occur in eutrophied habitats, it is apparently favored by conservative element contamination and can tolerate brackish water. It has been widely reported from the Great Lakes, including the Bay of Quinte (McCombie 1967) and Lake Ontario, where Munawar and Nauwerck (1971) cite *S. hantzschii* var. *pusilla* as being a characteristic spring bloom form. However, confusion regarding its taxonomy makes it difficult to discern consistent patterns in its occurrence.

During the IFYGL sampling period this species was abundant at most stations sampled during May 1972. Population densities declined at most stations sampled during June, and by July high population densities were largely restricted to a few mid-lake stations. Only scattered occurrences of *S. hantzschii* were found in samples from the August cruise, but populations of this species increased again in samples taken during October. This trend continued in November, and by February 1973 relatively high population densities were noted at stations near shore in the northeastern sector of the lake. By March there appeared to be a definite spring bloom at stations in the northern and eastern parts of the lake and an increase in population density at all nearshore stations. In our April samples, the very high population densities noted the previous month declined somewhat, but there was a tendency toward increase at most offshore stations, and very high population densities were recorded at stations 20, 35, 36, and 48 along the northern shore east of Toronto. Population densities of this species declined significantly again by the June cruise.

Stephanodiscus minutus Grun. (Fig. 27). This species usually occurs in the cold season phytoplankton of eutrophic or mesotrophic lakes. As is the case with other small species of the genus, distribution records are difficult to interpret because of taxonomic problems. Stoermer and Yang (1969) indicate that it is common in Lake Michigan and particularly abundant in eutrophied nearshore areas and harbors.

During the IFYGL sampling period it was present at most stations sampled during the May 1972 cruise and tended to increase, particularly at stations in the northern half of the lake, by June. Population densities declined at all except a few mid-lake stations sampled during July, and by August only isolated low-level populations were present. Low population densities continued at all sampling intervals through February 1973. In March, however, this species began to increase, and by April substantial populations were present at most stations sampled, with highest population densities occurring at the shoreward stations. Counter to the trend shown by many diatom species, high population densities were again noted at stations sampled during June 1973.

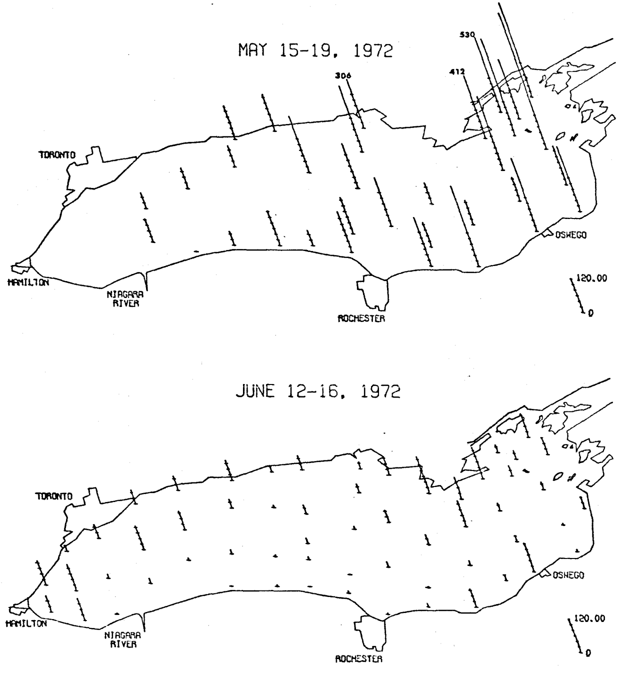
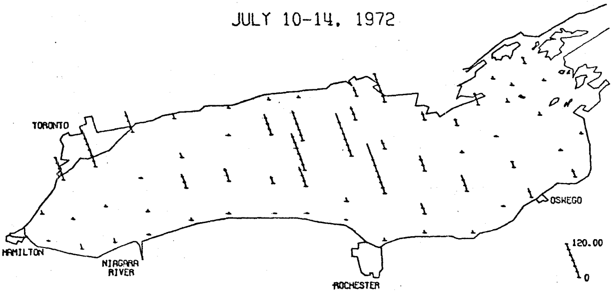


FIG. 26. Distribution of *Stephanodiscus hantzschii*.



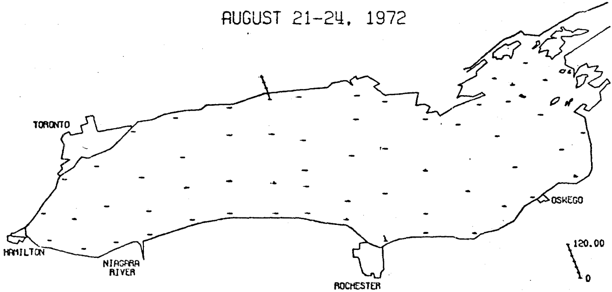


FIG. 26 continued.

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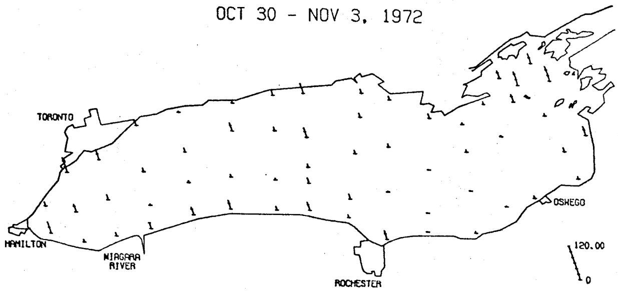


NOV 27 - DEC 1, 1972

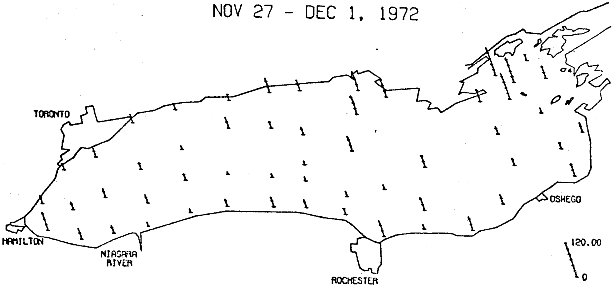
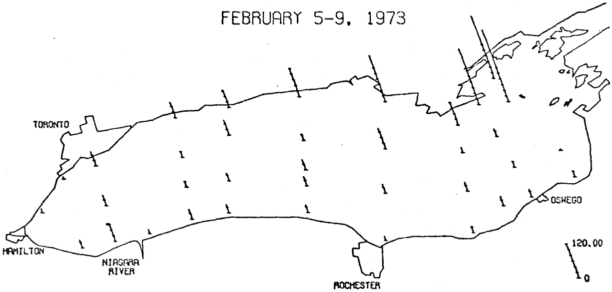


FIG. 26 continued.



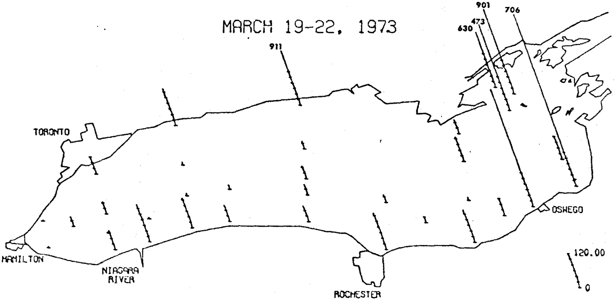
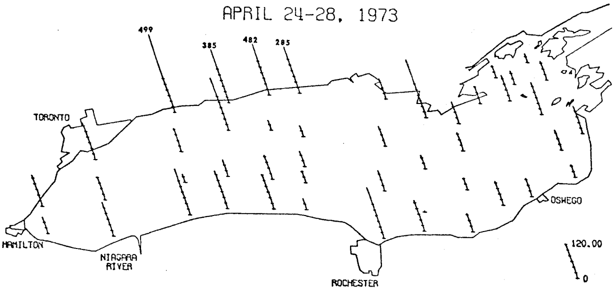


FIG. 26 continued.



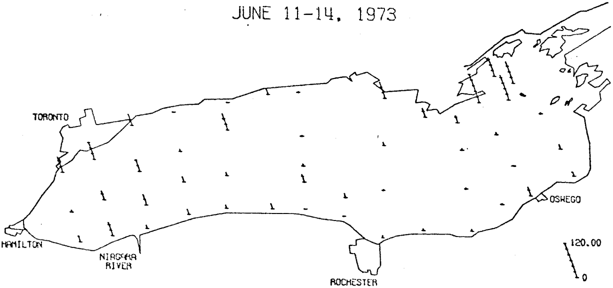


FIG. 26 continued.

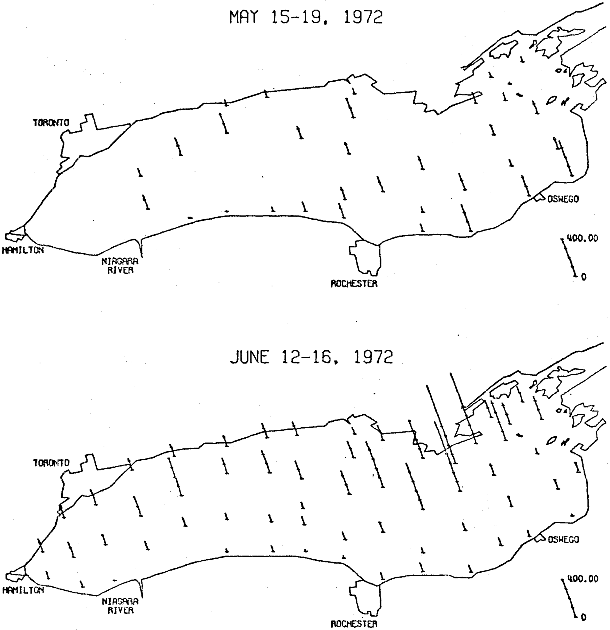
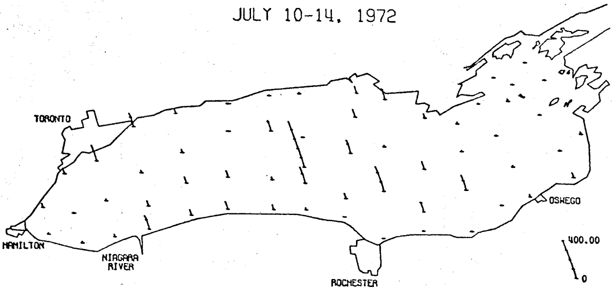


FIG. 27. Distribution of *Stephanodiscus minutus*.



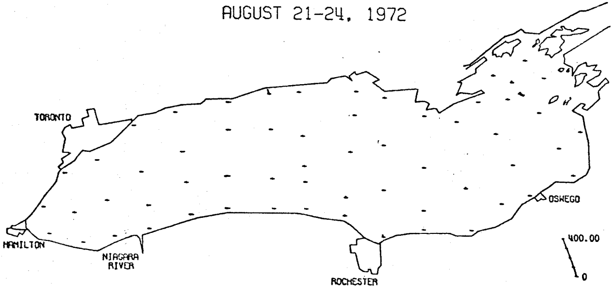
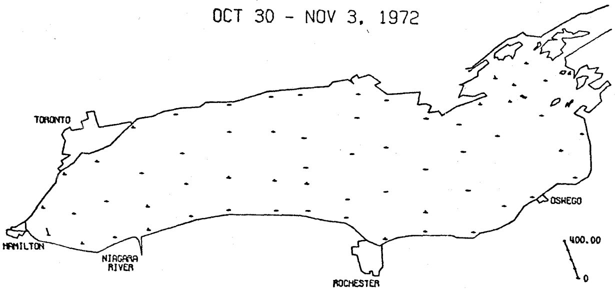


FIG. 27 continued.



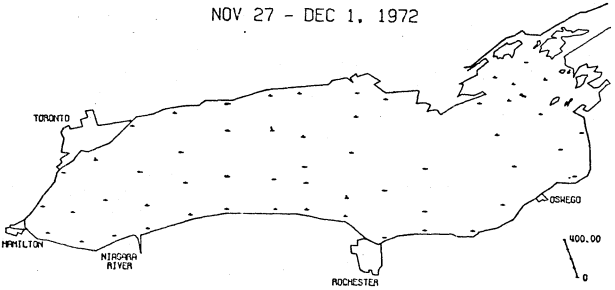
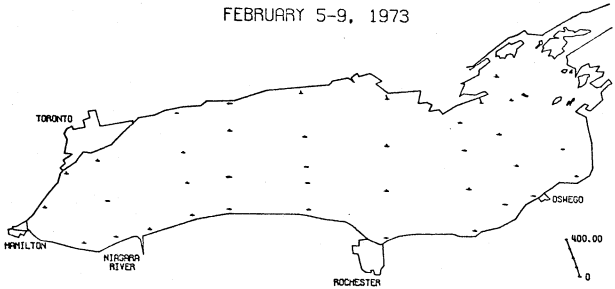


FIG. 27 continued.



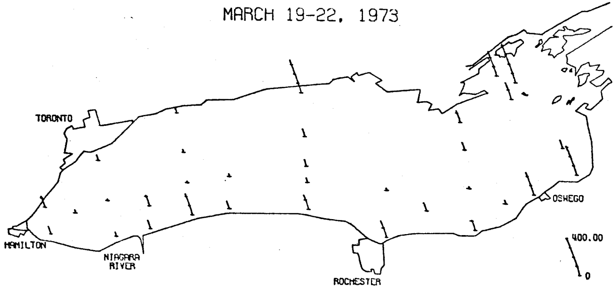
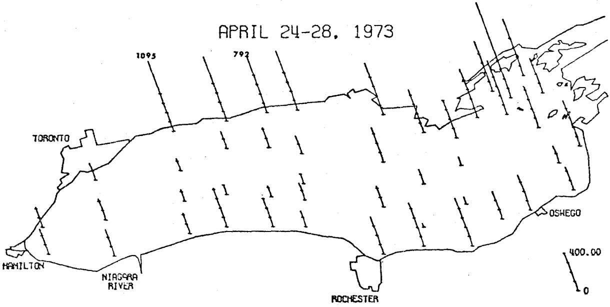


FIG. 27 continued.



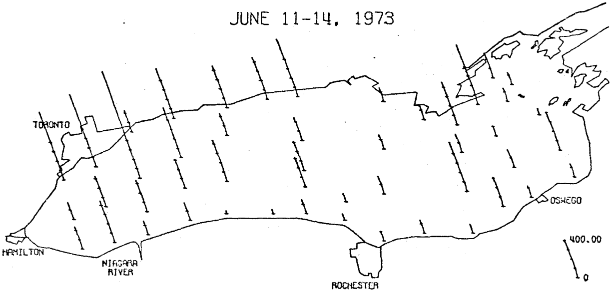


FIG. 27 continued.

Stephanodiscus subtilis (Van Goor) A. Cl. (Fig. 28). The distribution and ecology of this very small and delicately structured member of the genus is very poorly known. According to Cleve-Euler (1951) it reaches its highest population densities in highly eutrophic and "slightly salty" waters. According to Stoermer and Yang (1969) it is abundant in eutrophied nearshore waters and polluted harbors around Lake Michigan. Apparently it has not been reported previously from Lake Ontario although it may have been included in counts of other small members of the genus.

In our May 1972 samples, relatively high population densities of this species were found at nearshore stations in the southeastern sector of the lake. By June this distribution pattern had changed rather dramatically, with highest population densities being found at stations in the northern half of the lake. On the basis of samples collected during July, populations tended to decrease in the coastal areas in the eastern part of the lake, while remaining high at nearshore stations in the western part and at certain mid-lake stations in the eastern part. By August population densities were significantly reduced except at a limited number of stations in the vicinity of Rochester. Abundance remained rather low at stations sampled during August, except for stations 2 and 3 near Hamilton. Relatively low population densities of this species were found at stations sampled during November, and this apparent decline continued during February 1973. On the basis of samples from the March cruise, it appeared that a nearshore bloom of this species was developing, but this trend was not evident in the April samples. The June 1973 samples showed increased population densities of *S. subtilis* at stations in the southwestern part of the lake, but the abundance of this species never approached the levels found the previous spring.

Stephanodiscus tenuis Hust. (Fig. 29). This species appears to be associated with highly eutrophied waters in the Laurentian Great Lakes. Hohn (1969) lists it as one of the species which increased greatly in abundance in western Lake Erie in recent decades. It has apparently undergone similar increase in the eutrophied nearshore regions and polluted harbors bordering Lake Michigan (Stoermer and Yang 1969). On the basis of electron micrographs published by workers investigating the problem (Vaughn 1961) it appears that this species is, in fact, "the organism tentatively identified at *S. hantzschii*" which caused, together with *S. binderanus*, considerable problems at the Chicago filtration plant during the 1960's. It has been widely reported from Lake Ontario (Nalewajko 1966, 1967; Michalski 1968; Reinwand 1969; Munawar and Nauwerck 1971) and on the basis of these reports it appears to be consistently a dominant element of the spring diatom bloom. Similar to other small species of *Stephanodiscus* which have become abundant in the Laurentian Great Lakes in relatively recent years, this organism appears to be favored by elevated levels of conservative ions as well as increased nutrients.

In our May 1972 samples, population densities were high at stations

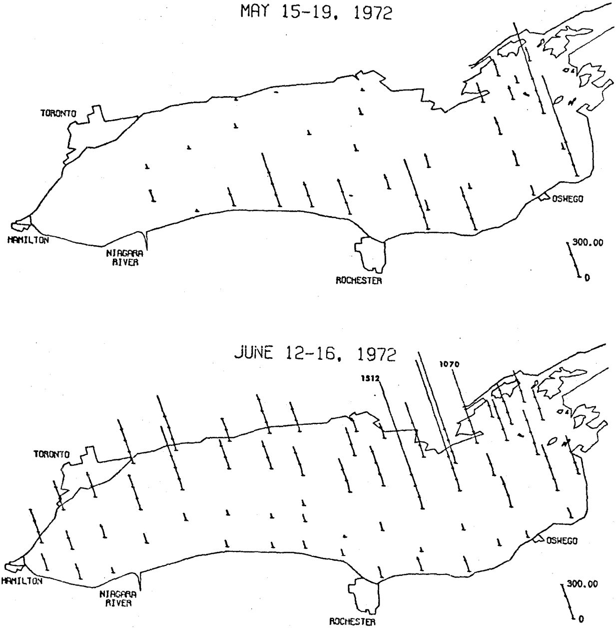
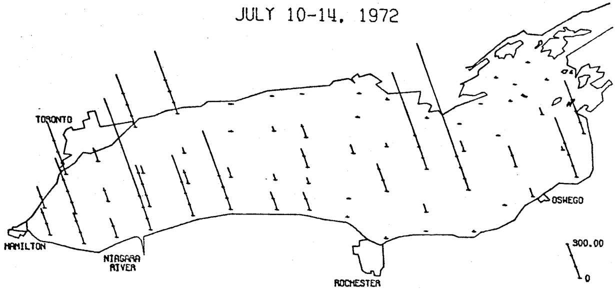


FIG. 28. Distribution of *Stephanodiscus subtilis*.



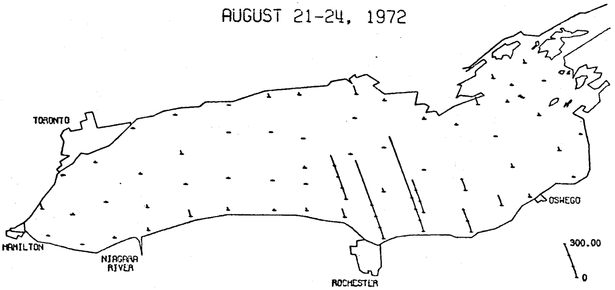
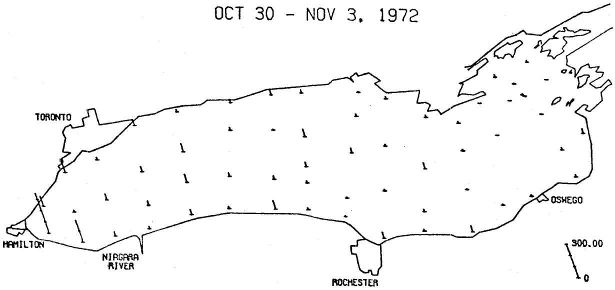


FIG. 28 continued.



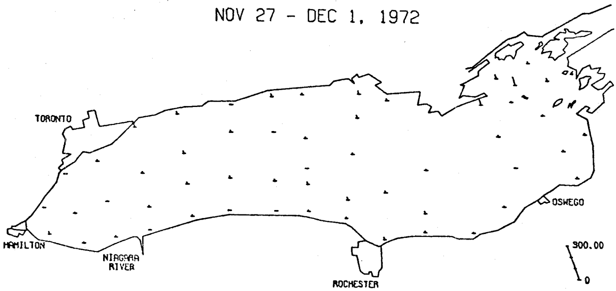
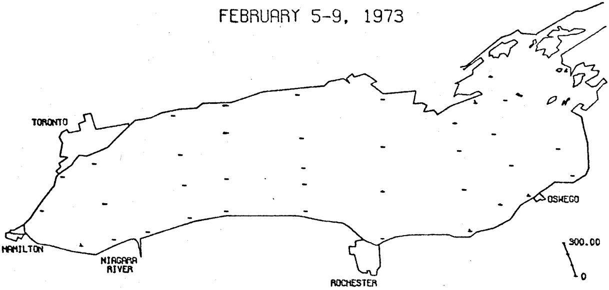


FIG. 28 continued.

FEBRUARY 5-9, 1973



MARCH 19-22, 1973

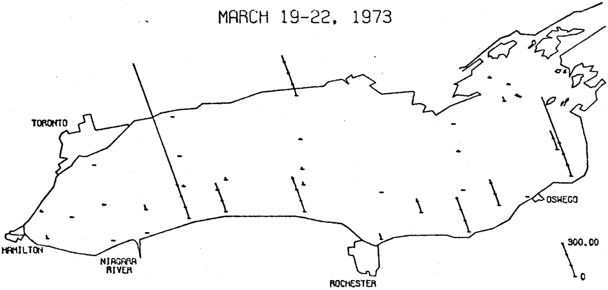
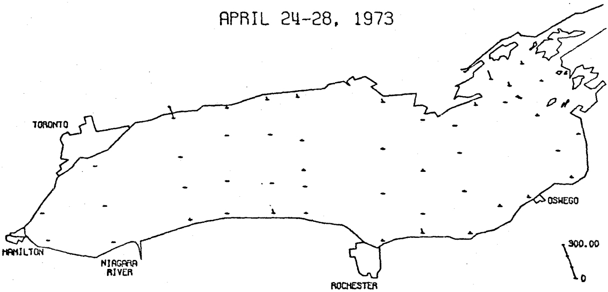


FIG. 28 continued.



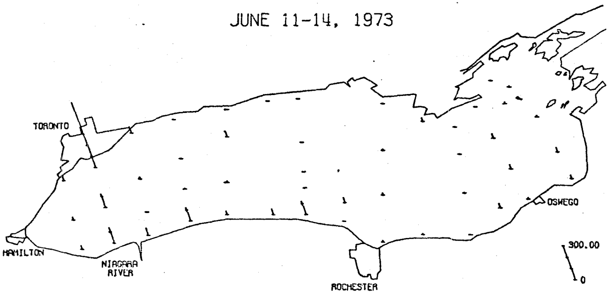


FIG. 28 continued.

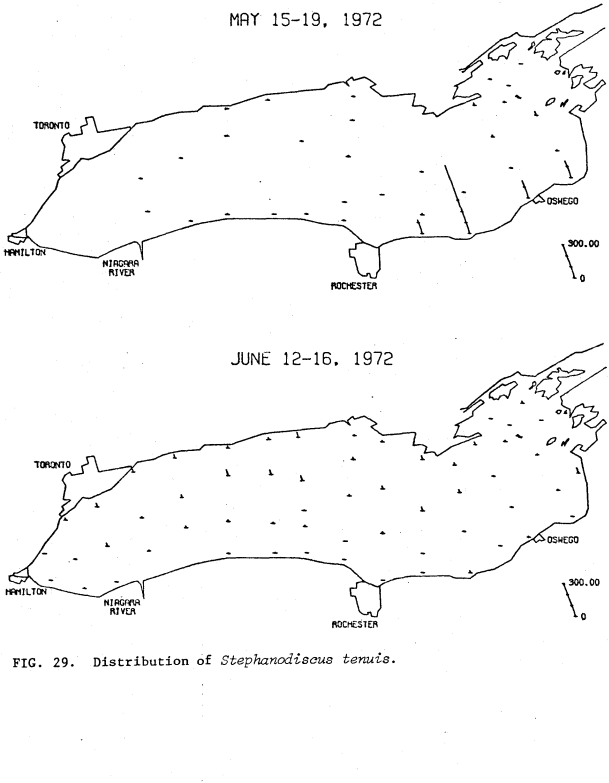
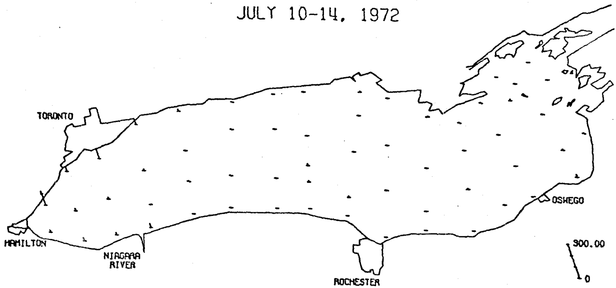


FIG. 29. Distribution of *Stephanodiscus tenuis*.



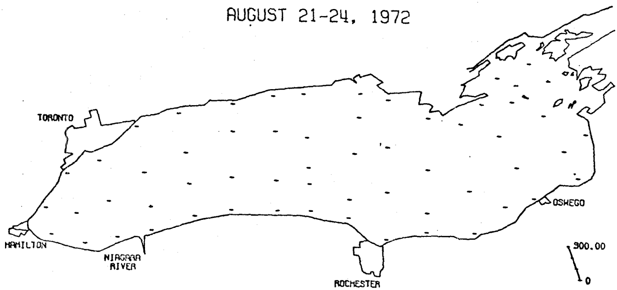
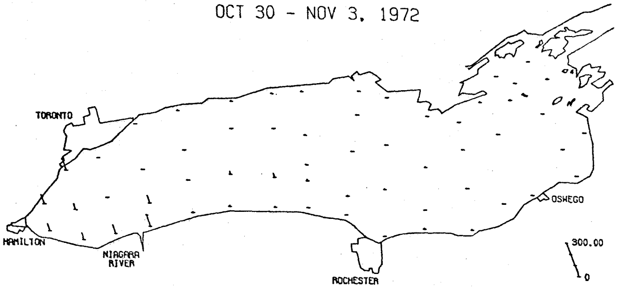


FIG. 29 continued.

OCT 30 - NOV 3, 1972



NOV 27 - DEC 1, 1972

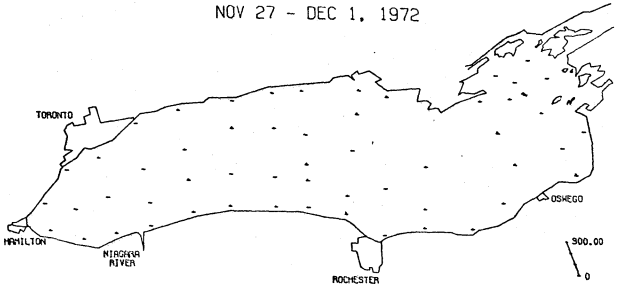
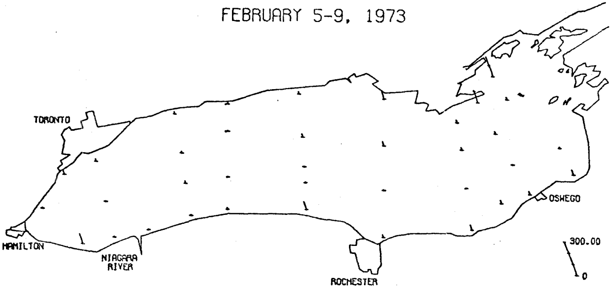


FIG. 29 continued.



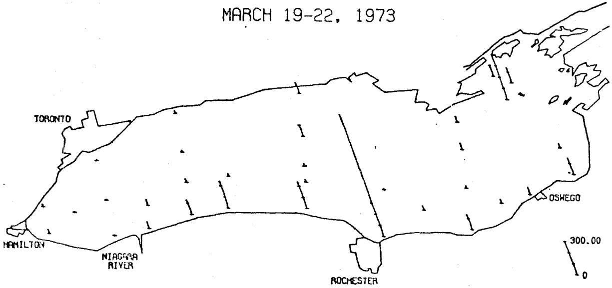
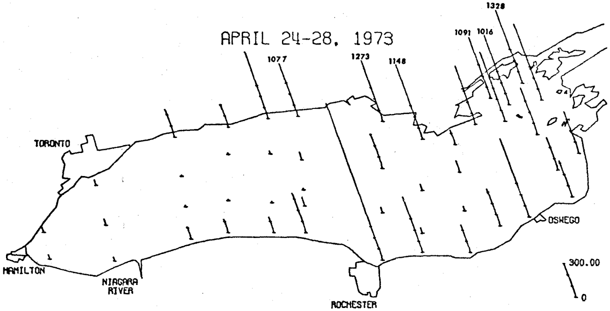


FIG. 29 continued.



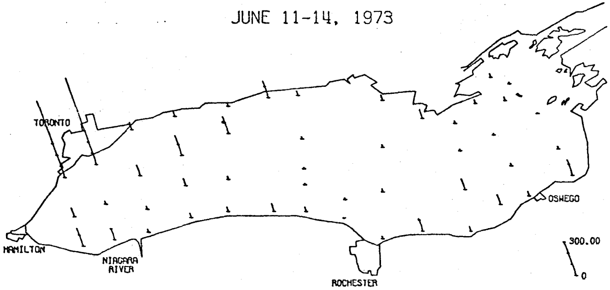


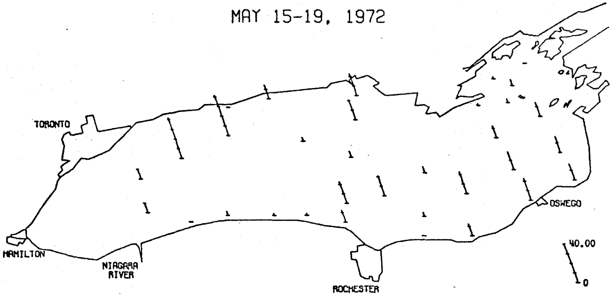
FIG. 29 continued.

nearest shore in the southeastern sector of the lake and very low at most stations. By the June sampling period somewhat elevated counts were noted at offshore stations, but the very high population densities noted at nearshore stations the previous month had been drastically reduced. Populations continued to decline except at a few nearshore stations between Hamilton and Toronto in July, by August only a few low level occurrences were noted. During the October cruise, increased population densities were noted at several stations in the western end of the lake, but by the November cruise only very low population densities were present at the stations sampled. A slight increase in the abundance of this species, particularly in some of the stations nearest shore, was found in the February 1973 samples in spite of reduced total phytoplankton abundance during this month. Samples taken during March 1973 indicated the beginning of a nearshore spring bloom of this species, particularly at station 60 near Rochester, and by April very high population densities were found at most nearshore stations in the eastern half of the lake. Population densities were significantly reduced at all stations sampled during June, except stations 7 and 8 near Toronto.

Surirella angusta Kütz. (Fig. 30). The abundance and wide distribution of this species in the phytoplankton of Lake Ontario is extremely unusual. Although several species of the genus are successful in the plankton of large lakes, most previous studies would indicate that *S. angusta* is primarily benthic in habitat preference. Skuja(1956) lists it in his discussion of the Swedish limnoplankton, but emphasizes that it is very rare and probably accidental in such collections. Huber-Pestalozzi (1942) does not even mention it in his extensive treatment of the planktonic members of the genus. Stoermer and Yang (1969) list it from a number of localities in Lake Michigan, but always in very low abundance. Hohn (1969) lists it as occurring in Lake Erie, but does not indicate that it was particularly abundant in his collections. Previous investigations of Lake Ontario phytoplankton (Munawar and Nauwerck 1971), however, list it as one of the major winter dominants. Although the population densities achieved by this species are not particularly great, it may be of considerable ecological importance because of its relatively great cell volume and because it is apparently most abundant when other species are at their yearly minimum. The factors which allow this species, which is usually associated with benthic habitats in eutrophic systems, to become important in the plankton community of Lake Ontario are not readily apparent.

In our collections from May 1972, *S. angusta* was present at most stations and quite abundant at many offshore stations. It declined drastically in the June samples and remained very scarce in the July and August collections. Slightly increased population levels were noted in October collections, particularly at stations relatively near shore. This trend continued in the November collections, and into February 1973, when total phytoplankton abundance was at its yearly low. Population densities of this species remained relatively high in our March collections, and reached their seasonal peak in April 1973. By June 1973, population

MAY 15-19, 1972



JUNE 12-16, 1972

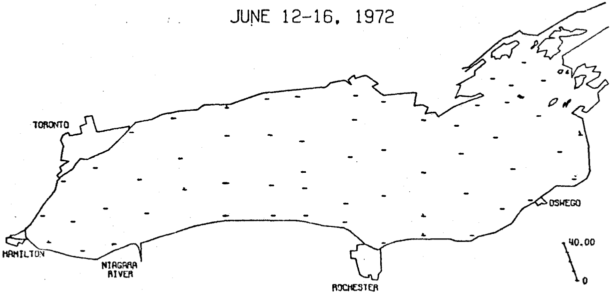
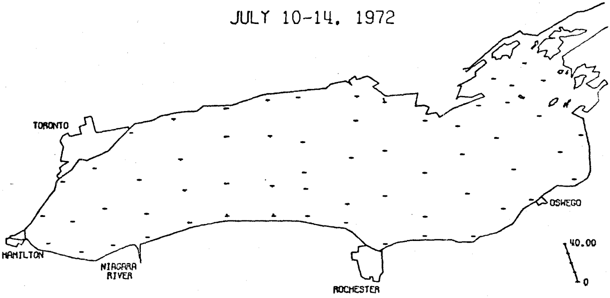


FIG. 30. Distribution of *Surirella angusta*.



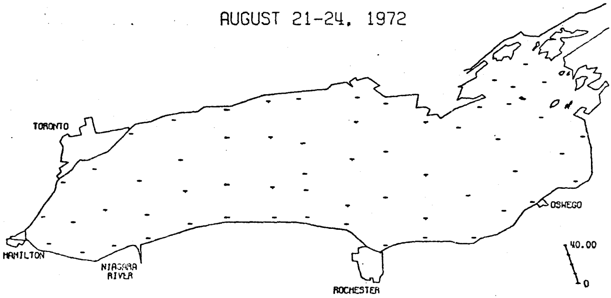
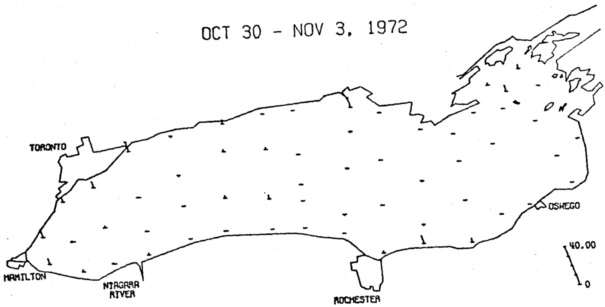


FIG. 30 continued.



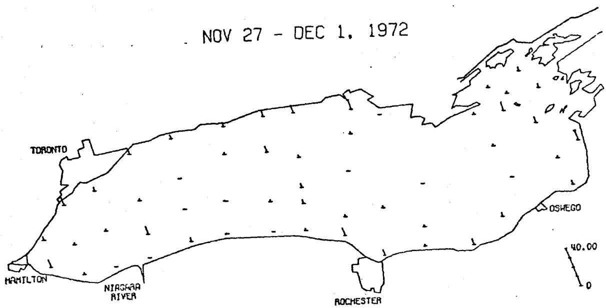
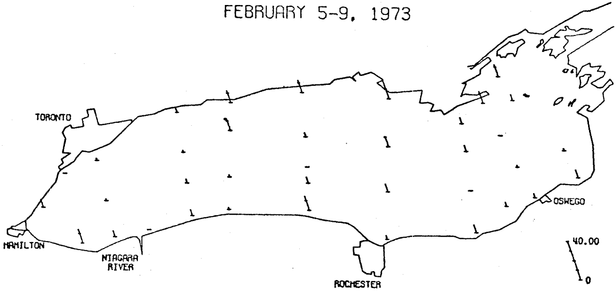


FIG. 30 continued.



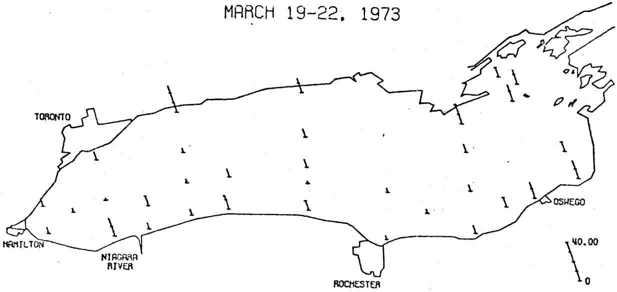
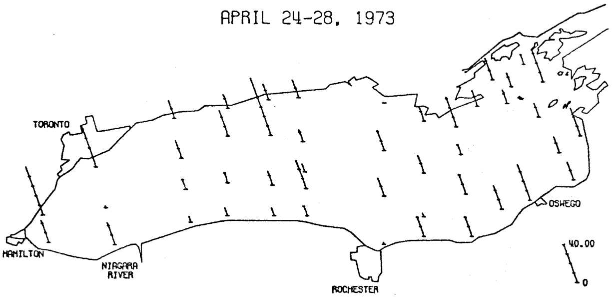


FIG. 30 continued.



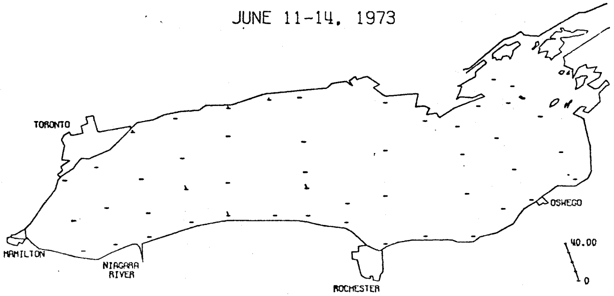


FIG. 30 continued.

levels had been reduced again to insignificant levels.

Synedra ostenfeldii (Krieg.) A. Cl. (Fig. 31). This species is one of the planktonic members of the genus which regularly occurs in colonies under optimal growth conditions. Individual cells are also found, especially following periods of peak abundance. The distribution and ecological affinities of this species are relatively poorly known. According to Cleve-Euler (1953) it is common in eutrophic lakes and rivers in Europe. Stoermer and Yang (1969) indicate that it is widely distributed in Lake Michigan with highest population densities occurring in eutrophied nearshore areas. Apparently it has not been reported previously from Lake Ontario specifically, although it is undoubtedly contained in several reports of the genus.

Although *S. ostenfeldii* was never particularly abundant in our collections, numerous occurrences were noted, and it seems to demonstrate a pronounced seasonal pattern of occurrence. Samples from the first cruise in May 1972 had few occurrences, although relatively large populations were noted at a few nearshore stations, particularly in the southeastern sector of the lake. Many more occurrences were noted in June samples, and highest population densities were found at stations in the eastern part of the lake which had not been sampled the previous month. Although occasional occurrences of this species were noted, its abundance remained low throughout the summer, fall, and winter sampling cruises. Samples taken during March 1973 showed slightly increased numbers, and a definite increase, particularly at stations in the far eastern part of the lake, was noted during April. Abundance increased further in June, with highest population densities occurring at offshore stations in the southern half of the lake.

Tabellaria fenestrata (Lyngb.) Kützing. (Fig. 32). This species is among the most common and widely distributed of the freshwater plankton diatoms. It occurs in abundance throughout the Laurentian Great Lakes and seems tolerent of most conditions. According to Hohn (1969) it is one of the taxa whose absolute frequency has not changed markedly in western Lake Erie in recent decades, although its relative abundance has decreased because of the introduction of exotic dominants. Considerable controversy surrounds the taxonomy of this taxon (Knudson 1952; Koppen 1973), and the apparent extreme range of adaptability of this species may be due to failure to recognize the true genetic entities involved.

During the IFYGL sampling period, this species was present at most stations in the northern part of the lake during the May 1972 sampling cruise and at a few other stations near shore. The same pattern continued during June, when there appeared to be a well defined zone of non-occurrence of *T. fenestrata* at offshore stations in the southern half of the lake. These populations apparently declined and, by the time of the July cruise, high population densities were largely restricted to a few offshore stations. The single exception to this was station 19,

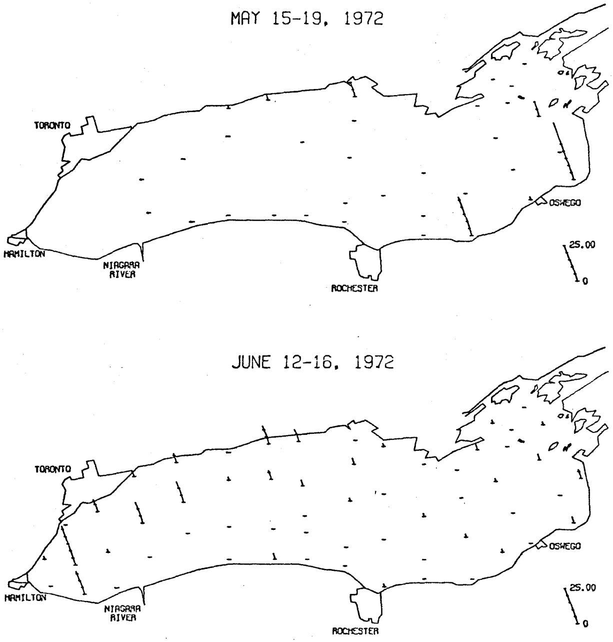
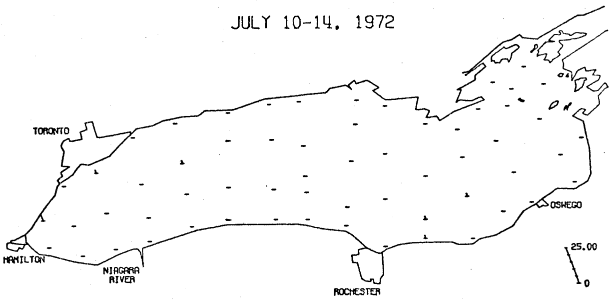


FIG. 31. Distribution of *Synedra ostenfeldii*.

JULY 10-14, 1972



AUGUST 21-24, 1972

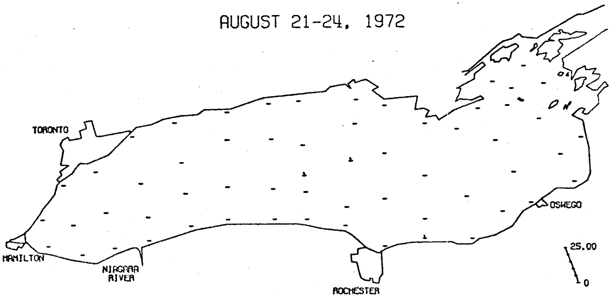
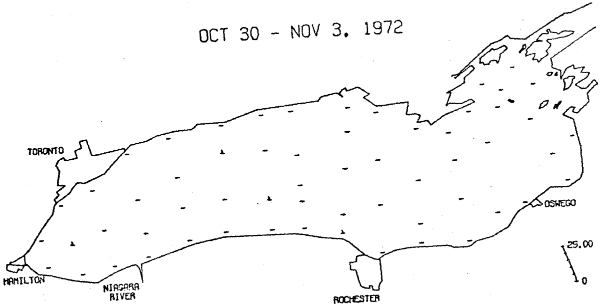


FIG. 31 continued.



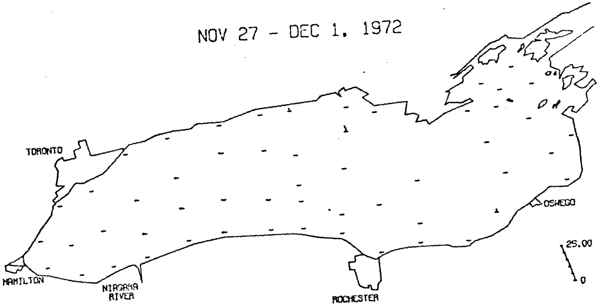


FIG. 31 continued.

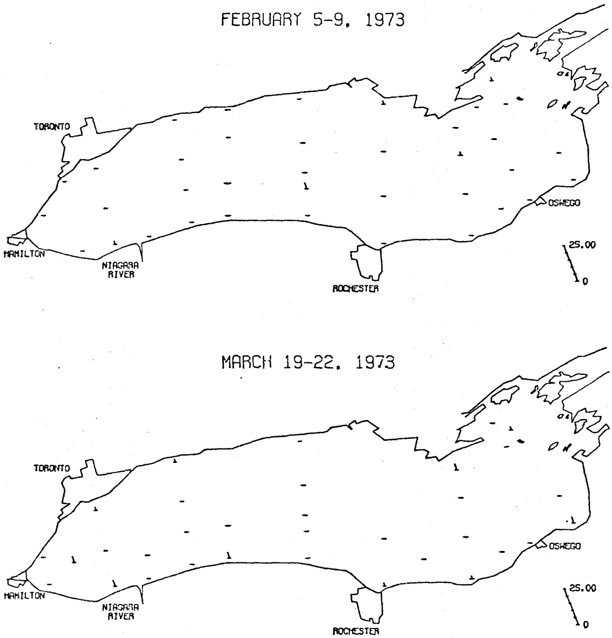
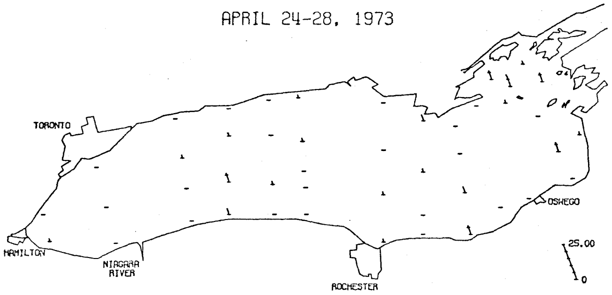


FIG. 31 continued.



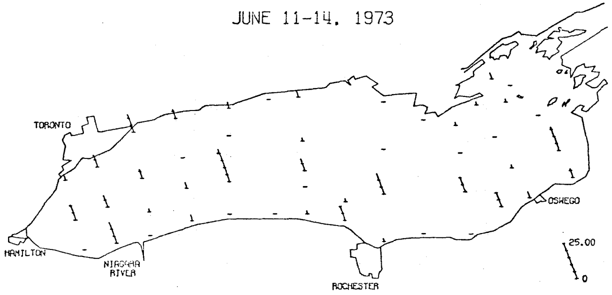


FIG. 31 continued.

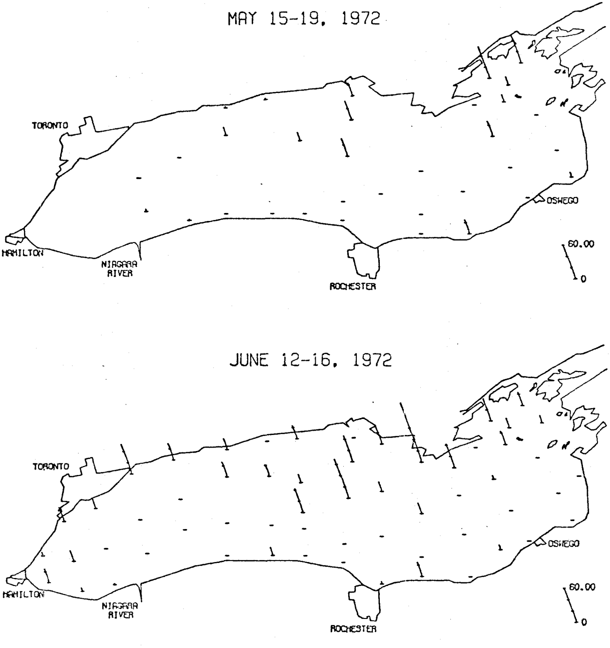
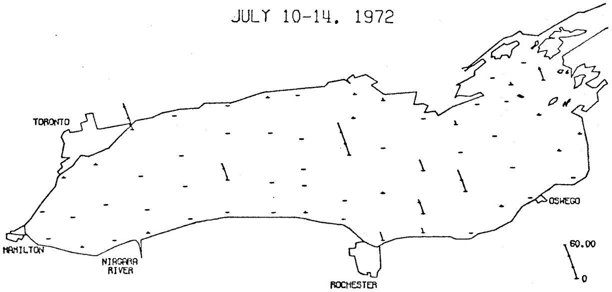


FIG. 32. Distribution of *Tabellaria fenestrata*.



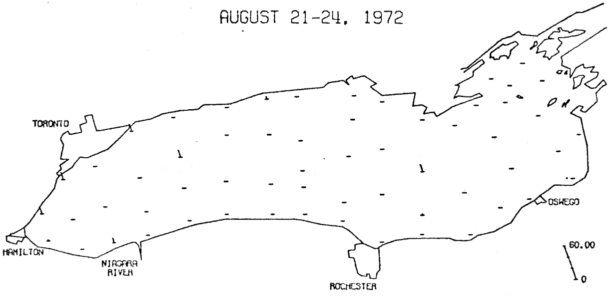


FIG. 32 continued.

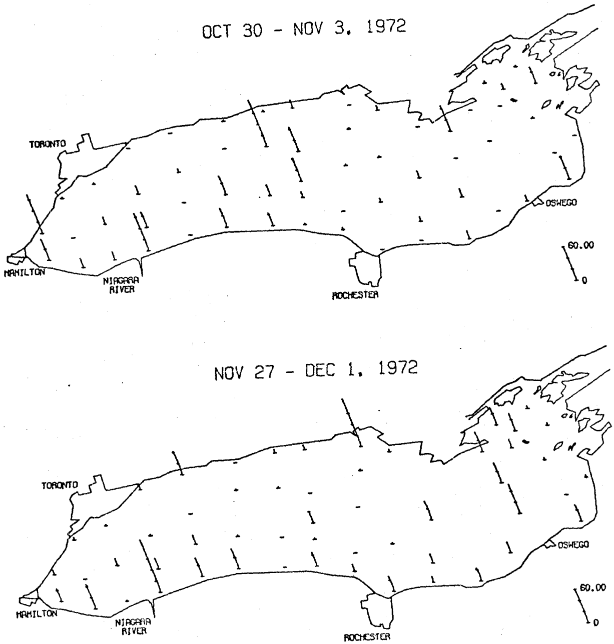
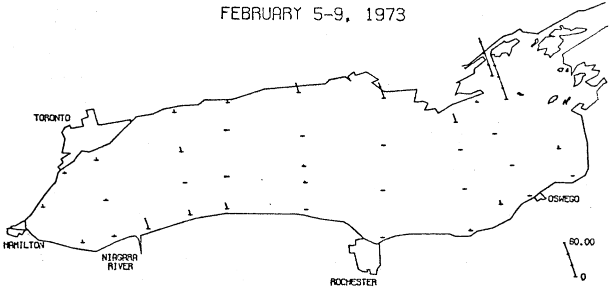


FIG. 32 continued.



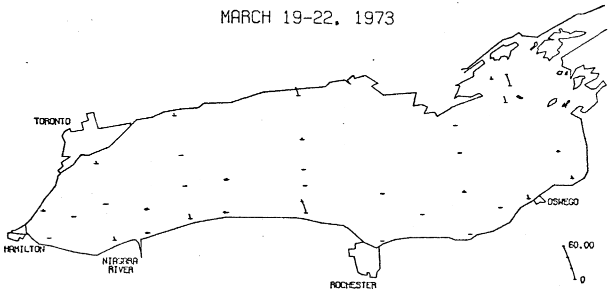
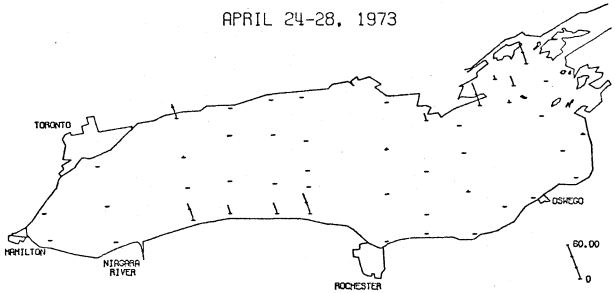


FIG. 32 continued.



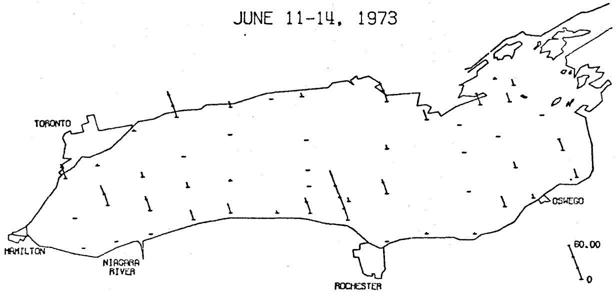


FIG. 32 continued.

near Toronto. The decline in abundance of *T. fenestrata* continued into August, when appreciable population densities were noted only at a few mid-lake stations and stations in the far western end of the lake. In October, however, population densities again increased at most stations. Population densities remained similarly high in samples taken during November, however there appeared to be a trend toward higher abundance at stations in the southern and eastern sectors of the lake at this time. By February 1973, population levels of *T. fenestrata* were considerably reduced, as was total phytoplankton density, except at stations 96 and 97 in the far eastern part of the lake. Reduced abundance was noted also in samples taken in March and April, with a tendency for highest population density to occur at stations nearest shore. Some increase in abundance of *T. fenestrata* was noted in June 1973 samples, however in 1973 populations appeared to be higher on the southern shore, unlike June 1972.

Chlorophyta

Ankistrodesmus falcatus (Corda) Ralfs (Fig. 33). Populations of this entity in Lake Ontario are somewhat unusual in that they generally fall in the lower size range commonly attributed to the species. Munawar and Nauwerck (1971), in their treatment of Lake Ontario phytoplankton, separated *A. falcatus* var. *spirilliformis* G. W. West from the nominate variety. All of the populations we have observed, however, tend to be intermediate in size and lack the characteristic shape of variety *spirilliformis* and we chose to treat them under the nominate variety.

Ankistrodesmus falcatus has been reported from many areas in the Laurentian Great Lakes, but high population densities are usually found only in eutrophied areas.

Low level populations were noted at most stations sampled during the May 1972 cruise, and high population densities occurred at several nearshore stations between Niagara and Rochester. Population densities of this species increased at most stations sampled during June 1972. Highest densities were present at stations in the far western region of the lake near Hamilton and on the southern shore, with exception of the stations near Niagara, where abundance was notably reduced. In this month there appeared to be a consistent pattern of low population densities of this species at stations running from Niagara offshore in the southern half of the lake. Unlike most species associated with the spring bloom, *A. falcatus* never achieved particularly high abundance in the eastern sector of the lake. Samples taken during July showed a general reduction in density of *A. falcatus*, although significant populations were still present at stations nearest shore in the eastern part of the lake and in Mexico Bay. Although previous investigations have characterized *Ankistrodesmus* spp. as summer (Munawar and Nauwerck 1971) or fall (Michalski 1968) forms, populations were considerably reduced in our August samples and remained at low levels in samples taken during the fall and winter cruises. The same situation

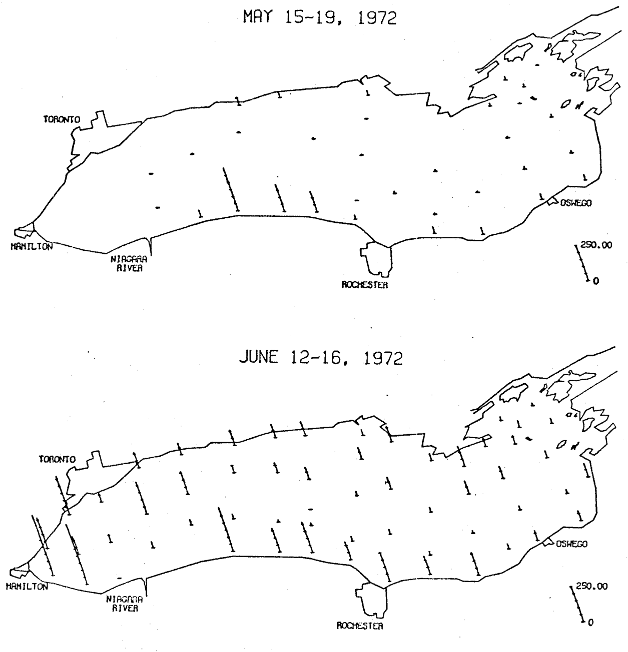
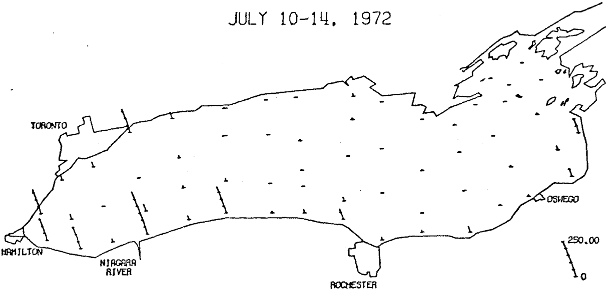


FIG. 33. Distribution of *Ankistrodesmus falcatus*.

JULY 10-14, 1972



AUGUST 21-24, 1972

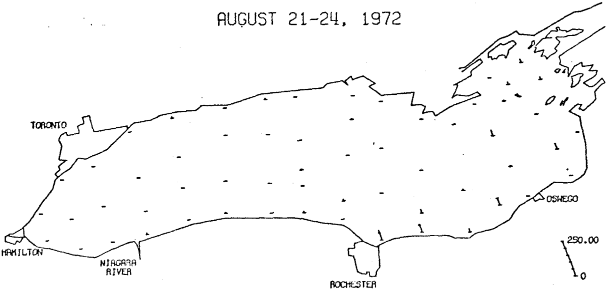
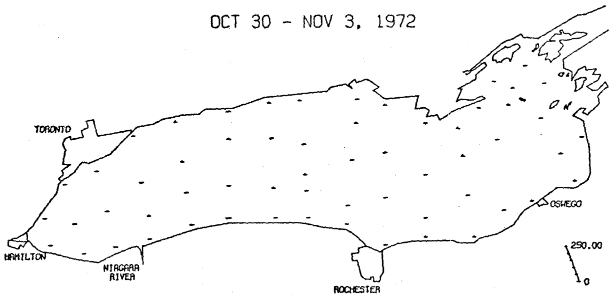


FIG. 33 continued.



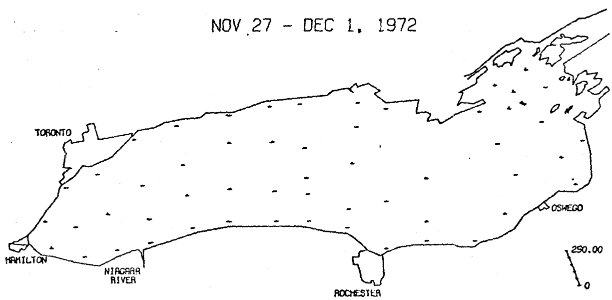
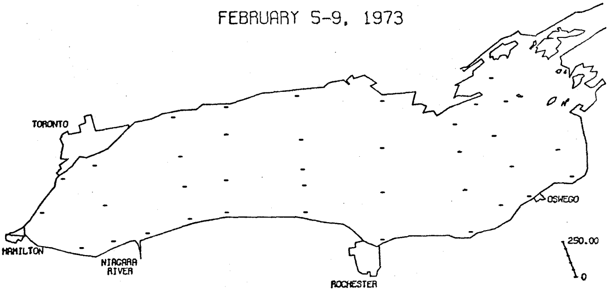


FIG. 33 continued.



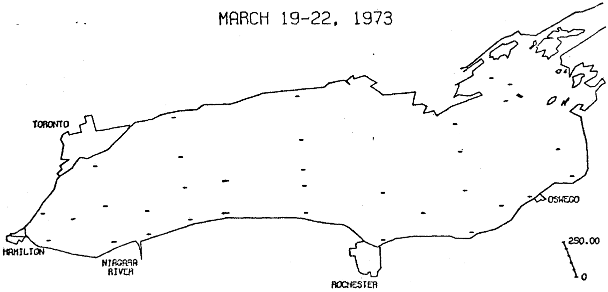
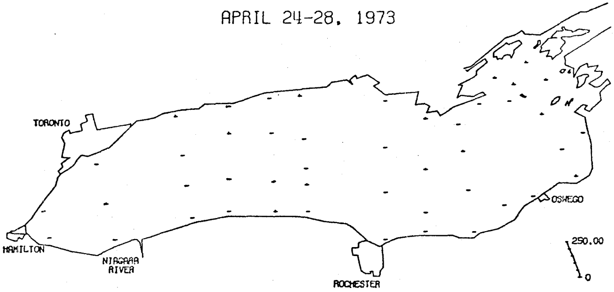


FIG. 33 continued.



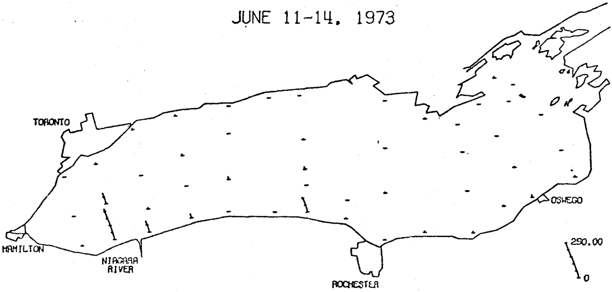


FIG. 33 continued.

obtained during the early spring sampling periods in 1973, and it was not until June 1973 that a few samples with population densities comparable to those found throughout the lake were found at stations near Niagara. If the lake-wide bloom of this species noted the previous year was repeated, this apparently did not take place until after termination of our sampling period.

Botryococcus braunii Kütz. (Fig. 34). This species has unusual distribution, occurring in both eutrophic and oligotrophic lakes in considerable quantities (Hutchinson 1967). Mature and scenescent colonies accumulate large quantities of fats and oils and tend to float near the surface. This, plus the fact that mature colonies are quite large, leads to uncertainties in estimates of its abundance made by standard phytoplankton enumeration methods. Although the distinctive colonies are visible in net plankton collections taken from almost any locality in the Laurentain Great Lakes during the late summer and fall, it is rarely reported in quantitative studies.

In our collections its occurrence was very restricted. A single occurrence at about 75 cells/ml was noted at station 35 in May. Aside from this, all other occurrences noted came from the month of August. During this sampling period *B. braunii* was present in considerable quantities at a number of stations sampled, particularly in the eastern and northeastern parts of the lake.

Coelastrum microporum Näg. (Fig. 35). This species is apparently quite widely distributed in the Laurentian Great Lakes, but only reaches appreciable abundance in eutrophic regions. Taft and Taft (1971) reports it from western Lake Erie, and we have observed it in collections from several localities in Lakes Michigan and Huron. In these lakes it occurs in greatest abundance in shallow, eutrophied areas such as Green Bay and Saginaw Bay. It has been reported from Irondequoit Bay of Lake Ontario (Tressler et al. (1953) and as a spring dominant in the open lake by Munawar and Nauwerck (1971). Several other records of *Coelastrum* sp. from Lake Ontario are likely referrable to this species.

It was not noted in our collections from the May and June 1972 cruises, and only isolated occurrences in the opposite ends of the lake were noted in July. By the time the August samples were taken, however, most stations sampled had populations of *C. microporum*, and it was quite abundant at stations in the eastern half of the lake. The population density of this species was greatly reduced in samples taken during October, and only a few populations were found in the November samples. A single occurrence was noted in samples taken during February, and it was apparently absent from samples taken during March and April 1973. In June 1973 a single, extremely high occurrence was noted at station 59 near Rochester.

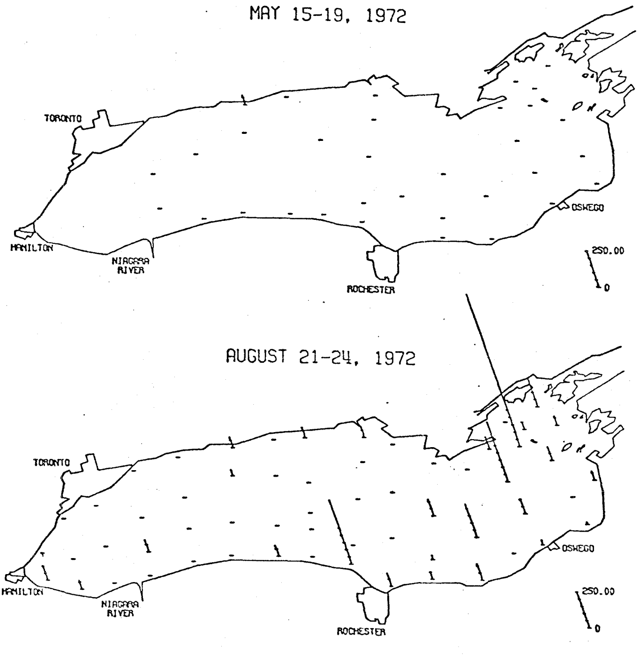


FIG. 34. Distribution of *Botryococcus braunii*.

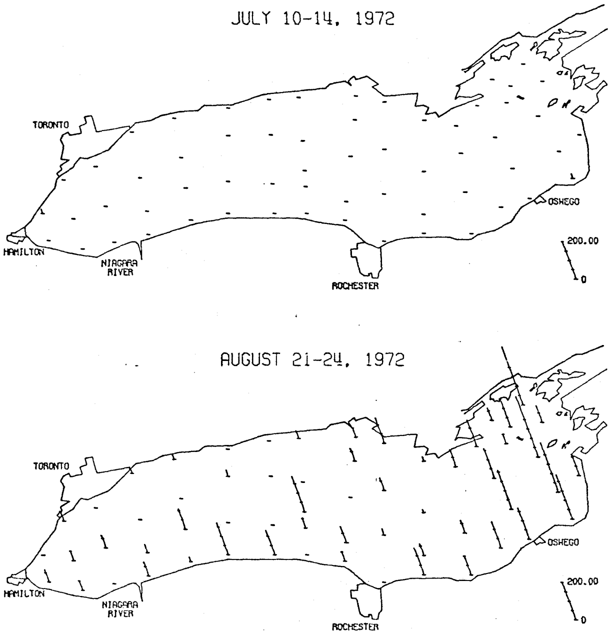
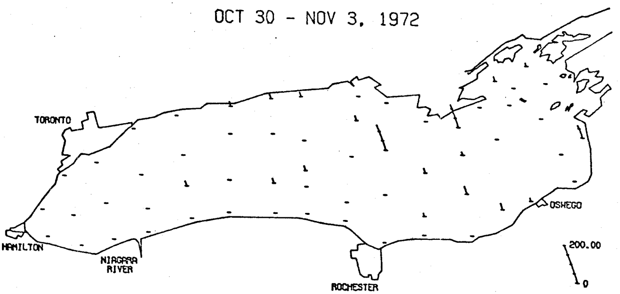


FIG. 35. Distribution of *Coelastrum microporum*.



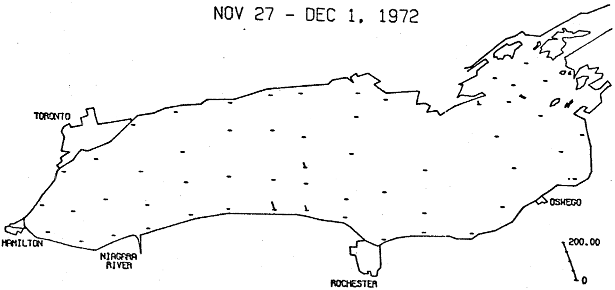
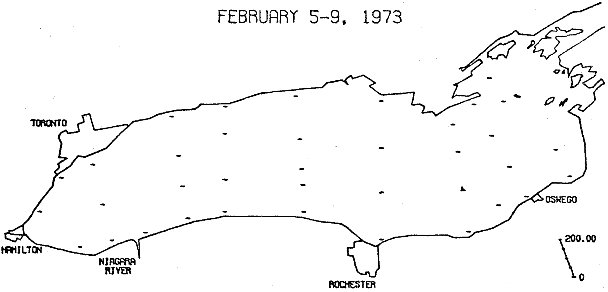


FIG. 35 continued.



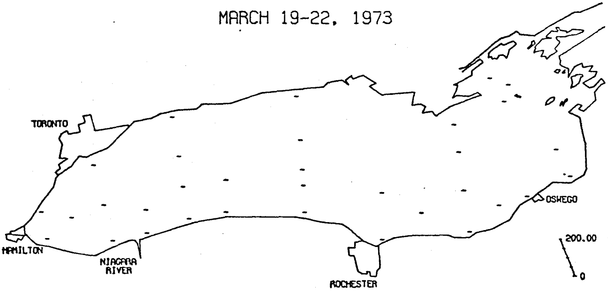
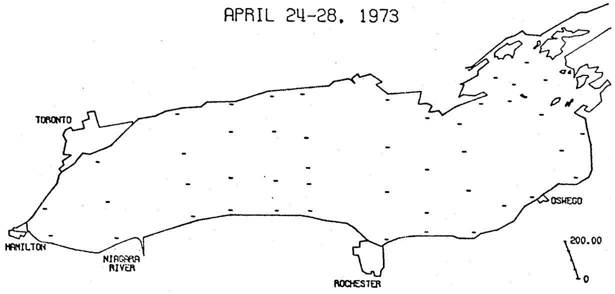


FIG. 35 continued.



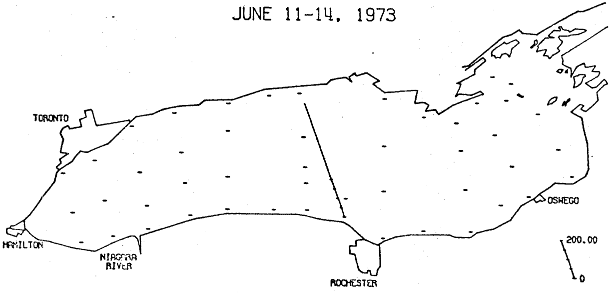


FIG. 35 continued.

Gloeocystis planctonica (West & West) Lemm. (Fig. 36). This species has been reported from a variety of habitats in certain regions of Europe (Skuja 1956) and, although not widely reported from the Great Lakes, we have found it to be one of the more abundant green algae in the plankton of Lake Michigan. Skuja (1948) has given an excellent account of the life cycle stages of this species, and we suspect that some of the previous reports of *Chlorella* spp., *Chlamydomonas globosa* Snow, and *Gloeocystis gigas* (Kütz.) Lag. from Lake Ontario may be referrable to it.

Moderate levels of abundance of this species were noted at stations along the southern shore in samples from the May 1972 cruise. By the time of the June cruise it had become widely distributed and populations were noted at most stations sampled, although there was a consistent pattern of non-occurrence at offshore stations in the southern half of the lake east of Niagara. High population densities were again noted in samples from the July cruise, especially in the southwestern sector of the lake and at isolated stations in the eastern part. An extremely high abundance of this species was found at station 14 near Niagara at this time. Somewhat reduced population densities were noted in the August samples, although the species was still present in significant quantities, particularly at stations in the northeastern part of the lake. Abundance of *G. planctonica* declined considerably in the October samples, and only scattered, low levels of occurrence were noted in samples from the November 1972 cruise and from the February, March and April cruises in 1973. Slightly increased levels of abundance of *G. planctonica* were noted in samples taken during June 1973, but population densities never approached those found the previous spring.

Oocystis spp. (Fig. 37). The major population included in this category is *O. parva* West & West, although minor populations of some of the other smaller species of the genus are present. Such species are a ubiquitous part of the summer phytoplankton in most parts of the Laurentian Great Lakes. In most offshore regions population levels of *Oocystis* spp. remain at low levels, although high population densities may be present in the more eutrophic regions.

The entities included in this category showed a pronounced seasonality in our samples. Scattered, low level populations were found in May, June, and July 1973 samples. August samples showed a lake-wide bloom, with a trend toward highest population densities in the eastern portion of the lake. Abundance of the species progressively declined during the October and November sampling periods, and only scattered, low level populations were found in the 1973 samples.

Pediastrum glanduliferum Benn. (Fig. 38). Although not widely reported from the Laurentian Great Lakes, this is apparently a fairly widely distributed euplanktonic species.

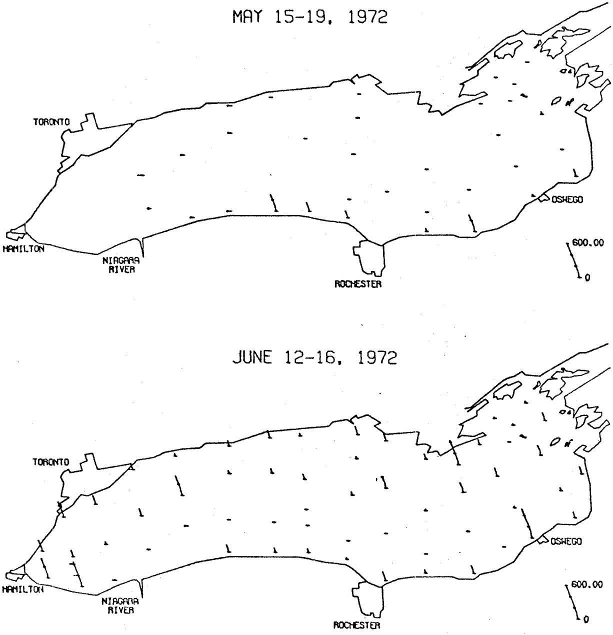
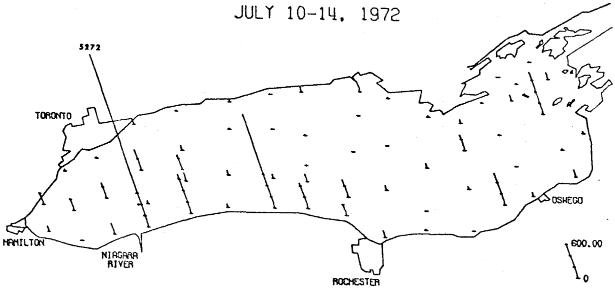


FIG. 36. Distribution of *Gloeocystis planctonica*.



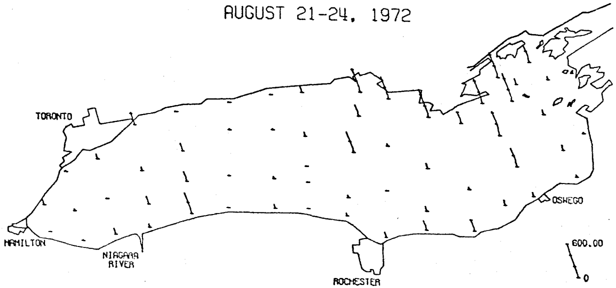
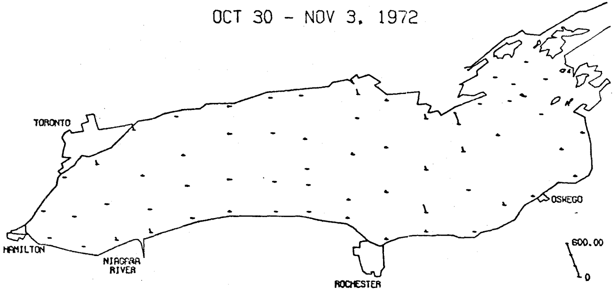


FIG. 36 continued.



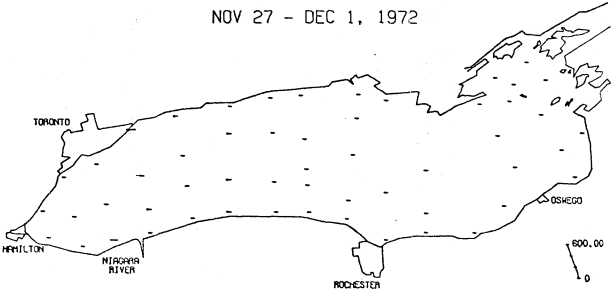
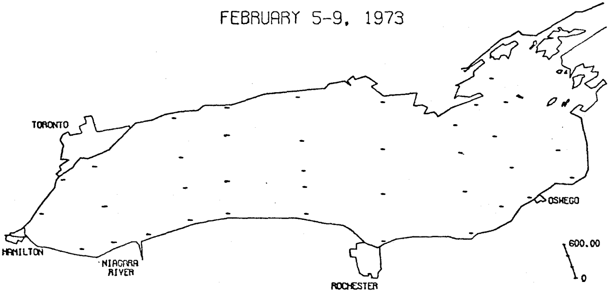


FIG. 36 continued.



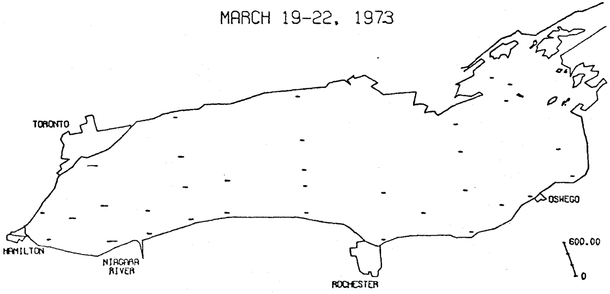
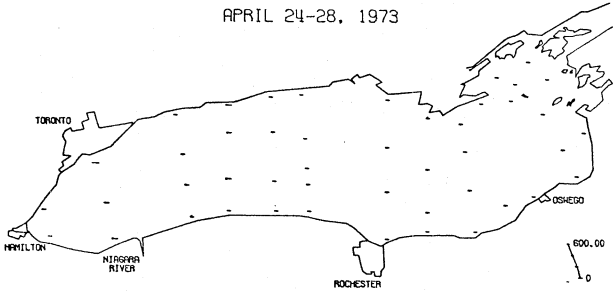


FIG. 36 continued.



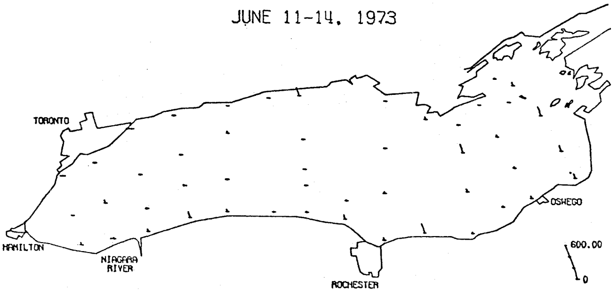
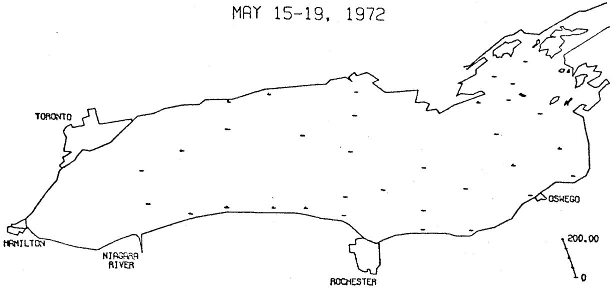


FIG. 36 continued.



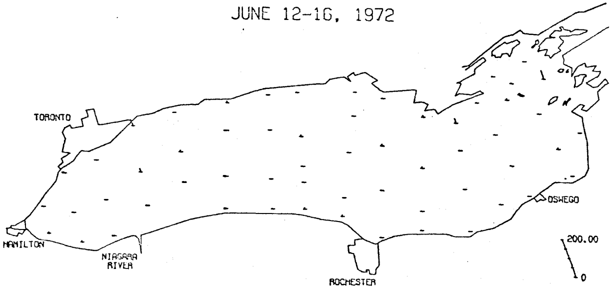
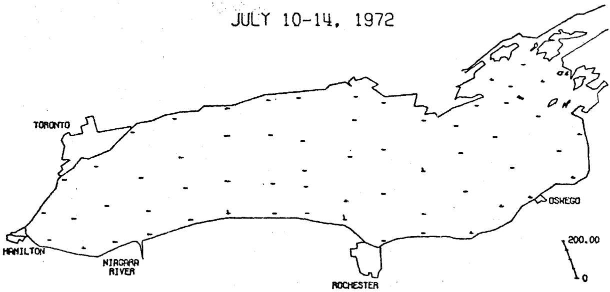


FIG. 37. Distribution of *Oocystis* spp.



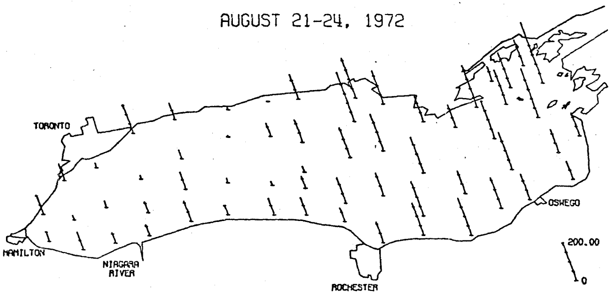
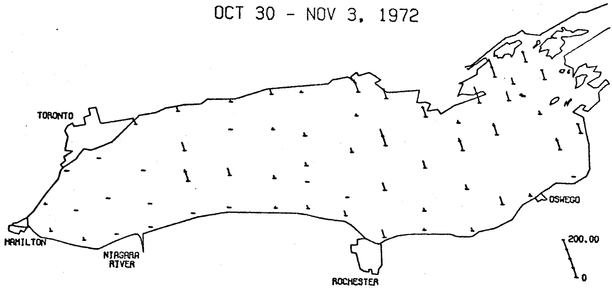


FIG. 37 continued.



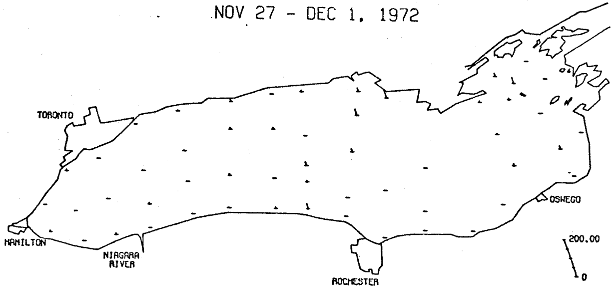
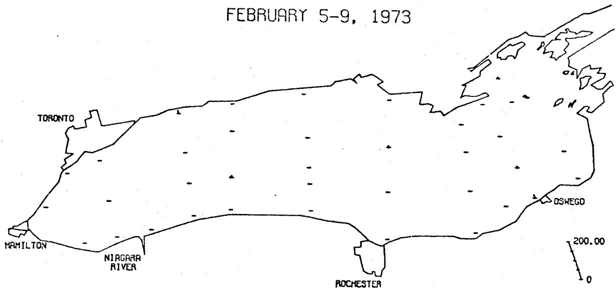


FIG. 37 continued.



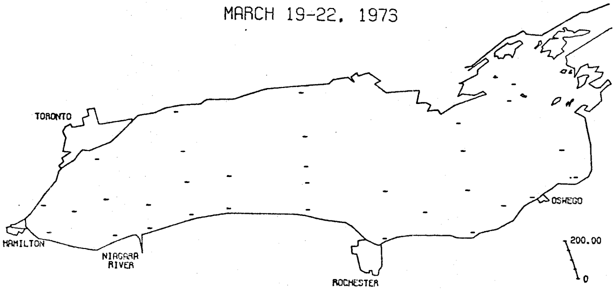
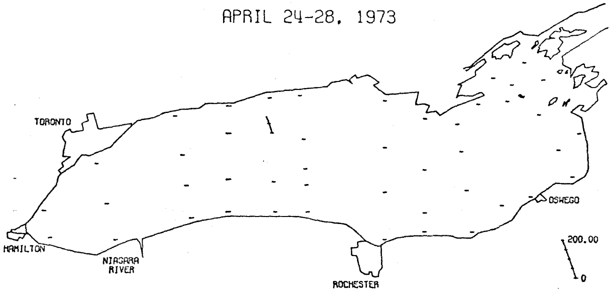


FIG. 37 continued.



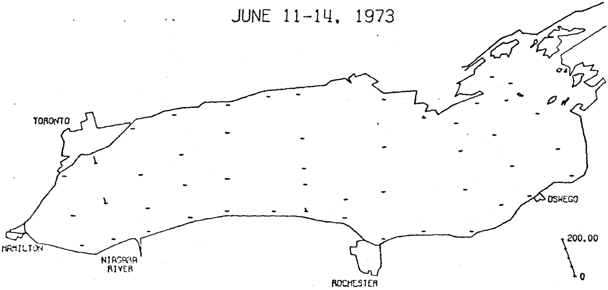


FIG. 37 continued.

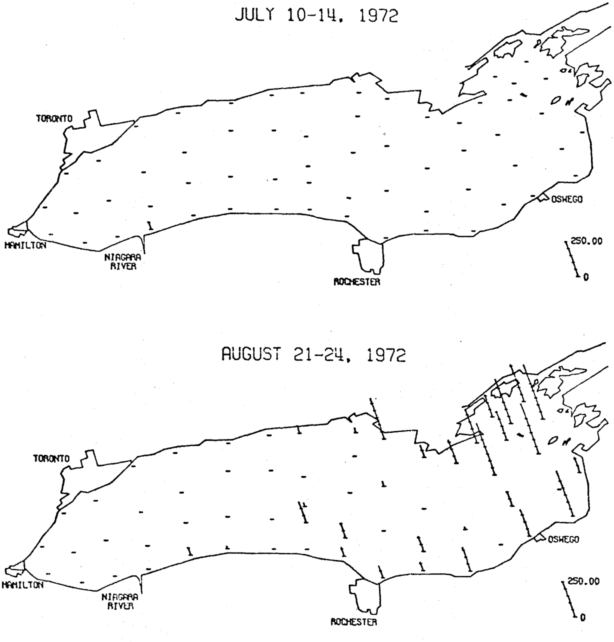


FIG. 38. Distribution of *Pediastrum glanduliferum*.

Its distribution in our samples from Lake Ontario is remarkably restricted. A single occurrence was noted at station 14 near Niagara in July. In August it was abundant at all stations east of Oswego and Pt. Petre and somewhat smaller populations were found at nearshore stations ranging west from this region. No occurrences were noted in samples from cruises either before or after these two months.

Phacotus lenticularis Ehr. (Fig. 39). This unusual chlorophycean flagellate has not been widely reported from the Great Lakes and relatively little is known about its distribution and ecological preference. We have found occasional populations in the in the upper lakes but it is usually a minor element of the flora. It is abundant in the summer plankton of some of the larger inland lakes in Michigan. In his review of the Swedish freshwater phytoplankton, Skuja (1956) indicates that it is widely distributed and is especially abundant in the summer. This tendency is strikingly apparent in our results.

Significant populations of this species were not noted in our samples from May and June 1972. In July, populations were noted at two stations in Mexico Bay. By August it had apparently undergone a lakewide bloom since significant populations were found at nearly every station sampled during the August 1972 cruise. In the rest of the months sampled, relatively small populations were noted with some tendency for largest populations to occur at stations in the far eastern part of the lake and at stations nearest shore in other parts of the lake.

Scenedesmus bicellularis Chodat (Fig. 40). Very little is known about the distribution and ecological affinities of this small species of *Scenedesmus* in the Laurentian Great Lakes. We have not found records of it from Lake Ontario, although specimens referred to *S. bijuga* and its varieties (Ogawa 1969; Munawar and Nauwerck 1971) may be included in *S. bicellularis* as treated here.

This species was very abundant at stations sampled during the first biology-chemistry cruise of the IFYGL during May and no particular geographical trends in its distribution were apparent. It continued to be very abundant at stations sampled during the June cruise, but at this time there appeared to be a consistent tendency toward reduced numbers at stations nearest the south shore of the lake. Unlike most of the species of green algae noted in the Lake Ontario phytoplankton, *S. bicellularis* had a pronounced summer minimum and the July and August samples contained relatively insignificant populations. A slight increase in abundance was found in samples collected during October, and small populations were also found in November 1972 and February 1973 cruises. Nearly stable populations were apparently present during March and April and, although significant increases in population density were noted at a few stations in the western part of the lake in June, the abundance of this species never approached the levels found the previous spring.

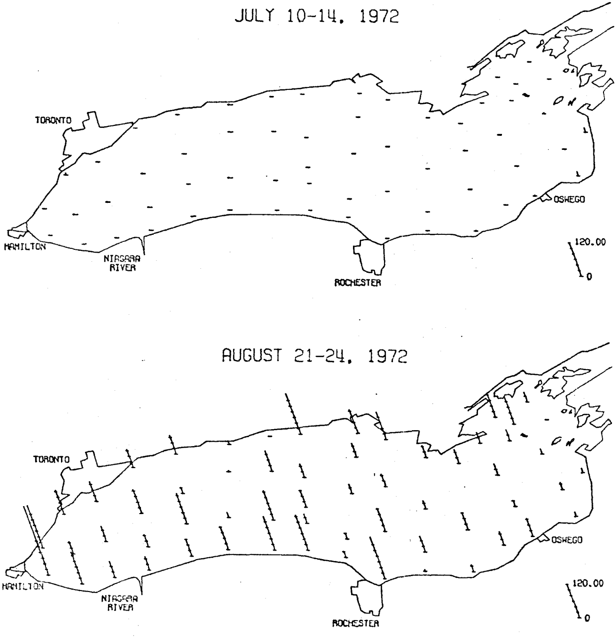
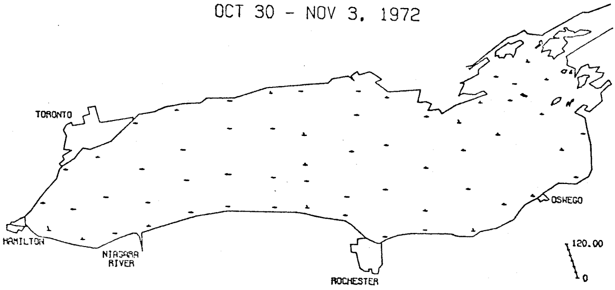


FIG. 39. Distribution of *Phacotus lenticularis*.

OCT 30 - NOV 3, 1972



NOV 27 - DEC 1, 1972

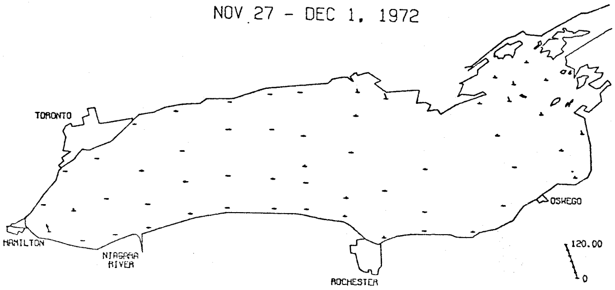
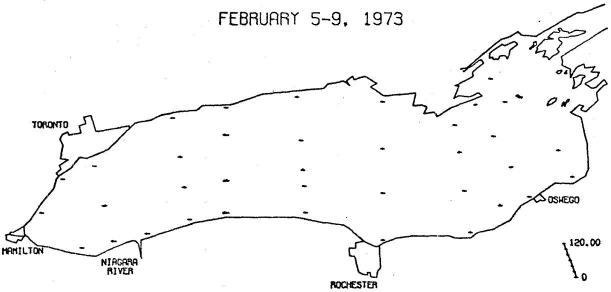


FIG. 39 continued.

FEBRUARY 5-9, 1973



MARCH 19-22, 1973

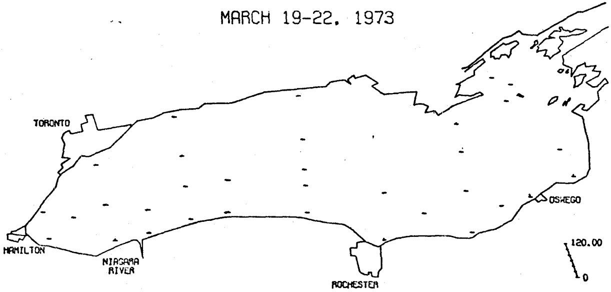
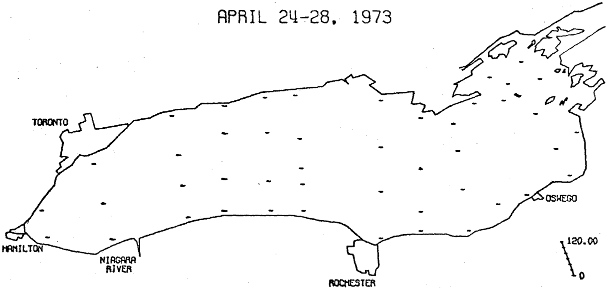


FIG. 39 continued.



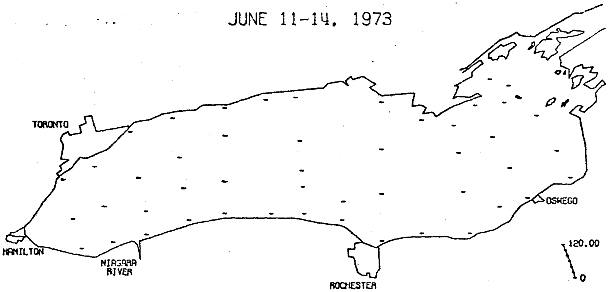
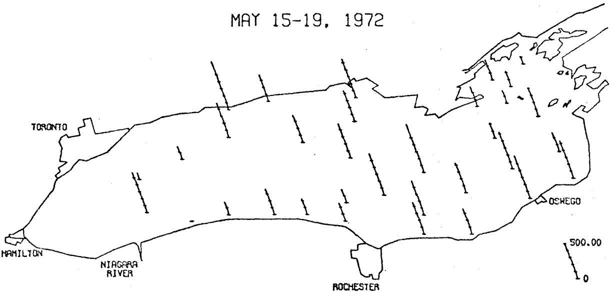


FIG. 39 continued.



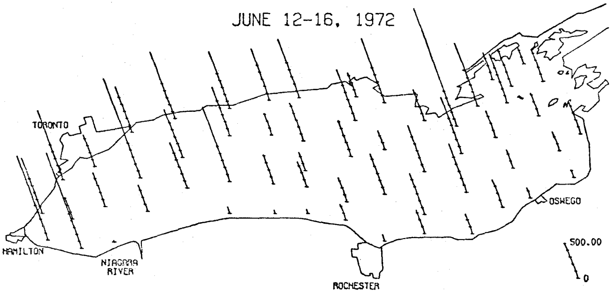
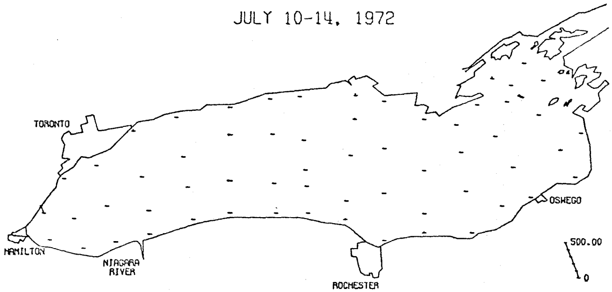


FIG. 40. Distribution of *Scenedesmus bicellularis.*



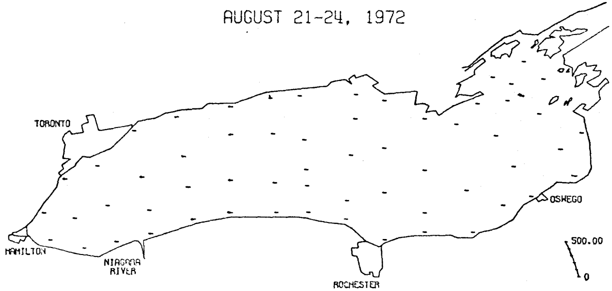
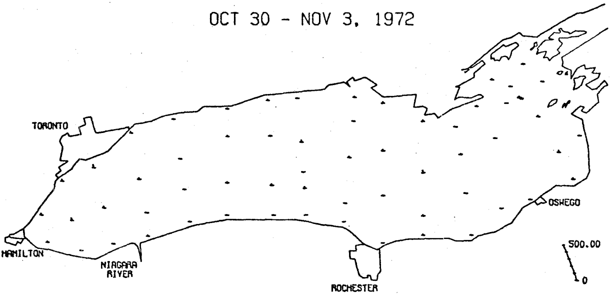
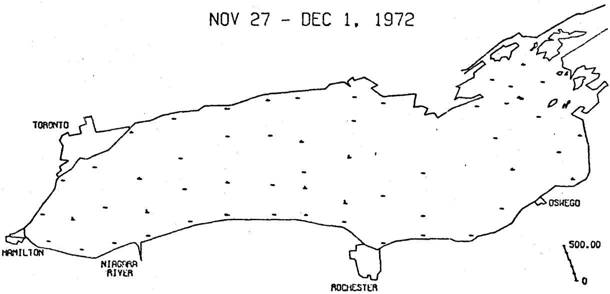


FIG. 40 continued.

OCT 30 - NOV 3, 1972



NOV 27 - DEC 1, 1972



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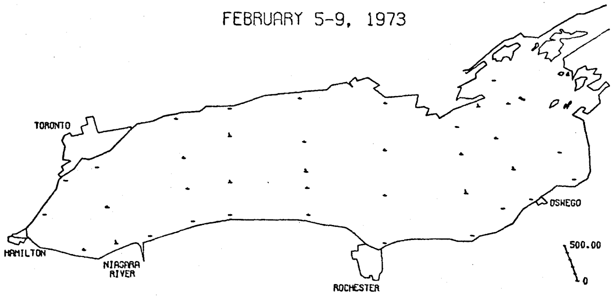


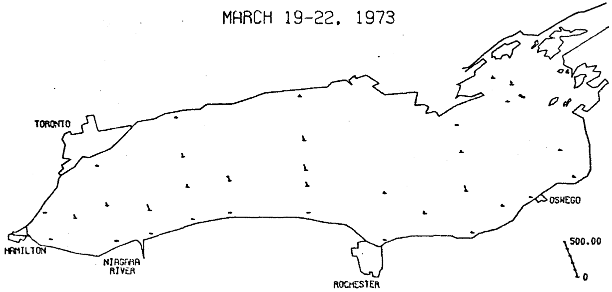
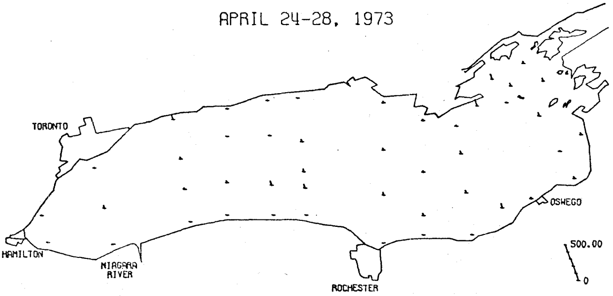


FIG. 40 continued.



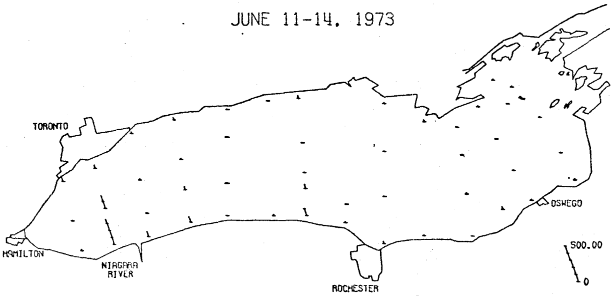


FIG. 40 continued.

Scenedesmus quadricauda var. *longispina* (Chodat) G. M. Smith (Fig. 41). According to Skuja (1956) this taxon is most common in small ponds, and is rarely found in abundance in larger lakes. This is somewhat surprising since our observations would tend to indicate that it is common in the more eutrophied portions of the Laurentian Great Lakes. It has been recorded as being widely distributed in western Lake Erie (Tiffany 1934; Taft and Taft 1971). *Scenedesmus quadricauda* var. *maximus* was listed from Irondequoit Bay of Lake Ontario (Tessler et al. 1953) and the nominate from stations in the open lake by Nalewajko (1966). Although not particularly abundant in our collections, this taxon is consistently present over a considerable part of the IFYGL sampling period.

Only two isolated populations of *S. quadricauda* var. *longispina* were noted in collections taken during the May 1972 sampling cruise. Both occurred at nearshore stations in the southeastern sector of the lake. In samples taken during the June cruise an increased number of occurrences were noted, still mostly at nearshore stations. Similar distribution was noted in the July samples, with occurrences being restricted to stations nearest the south shore. In August populations of *S. quadricauda* var. *longispina* occurred at most stations in the far eastern part of the lake, with isolated occurrences at stations along the northern shore and in the offshore waters. This species was much more generally distributed in our October samples although it still appeared at stations nearest shore or in the eastern part of the lake. Populations declined in the November samples with significant populations being largely restricted to offshore stations, although levels near those of the previous month were maintained at stations 8 and 19, near Toronto. Only a single population was noted in samples from the February cruise and this species was not recorded from samples taken during March. Isolated populations occurred in samples taken during April at stations nearest the southern shore, and the population density of *S. quadricauda* var. *longispina* increased significantly in samples taken during June 1973 particularly from stations nearest the southern shore.

Scenedesmus quadricauda var. *quadrispina* (Chodat) G. M. Smith (Fig. 42). This entity is quite easily separated from the previous one on classical taxonomic characteristics, however, in light of the known plasticity of such characteristics under different culture conditions (Trainor and Hilton 1963; Trainor 1966; Trainor and Roskosky 1967) it is tempting to speculate that both may be ecophenes of the same genetic entity. The very limited distribution of *S. quadricauda* var. *quadrispina* might be interpreted as supporting such a supposition, but our observations do not furnish a plausible basis for resolving the question. In any case, the difference in distribution of the two morphological entities must reflect environmental differences at the stations sampled.

No occurrences of *S. quadricauda* var. *quadrispina* were noted during the first two IFYGL biology-chemistry cruises. Limited populations were found in July at stations in opposite ends of the lake. In August, however, appreciable populations were found at most stations in the

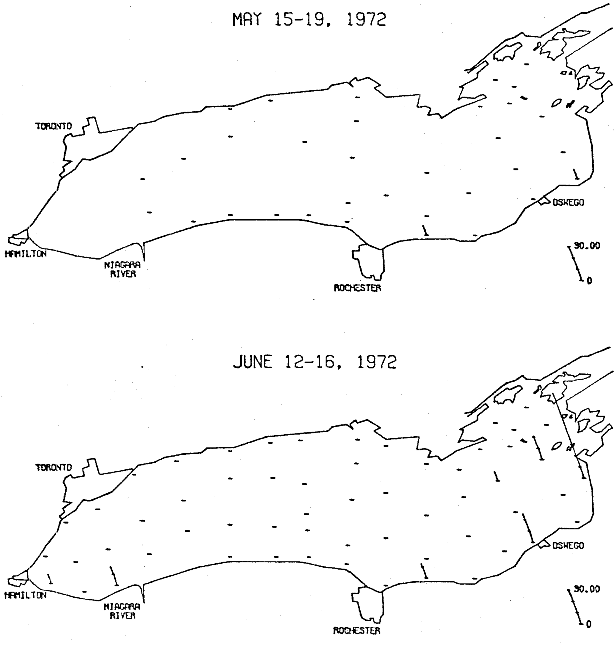
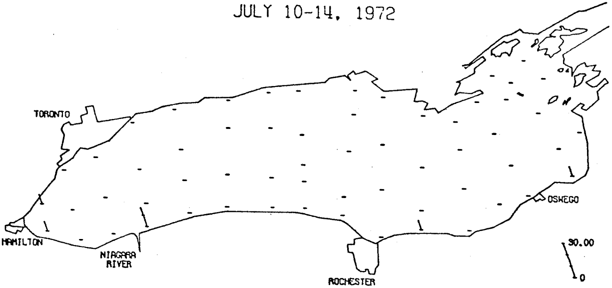


FIG. 41. Distribution of *Scenedesmus quadricauda* var. *longispina*.

JULY 10-14, 1972



AUGUST 21-24, 1972

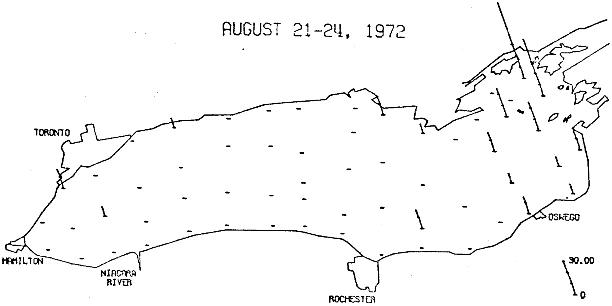
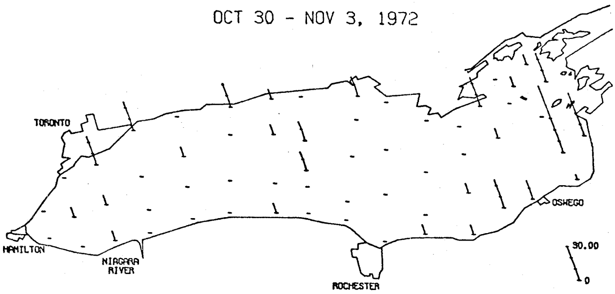


FIG. 41 continued.

OCT 30 - NOV 3, 1972



NOV 27 - DEC 1, 1972

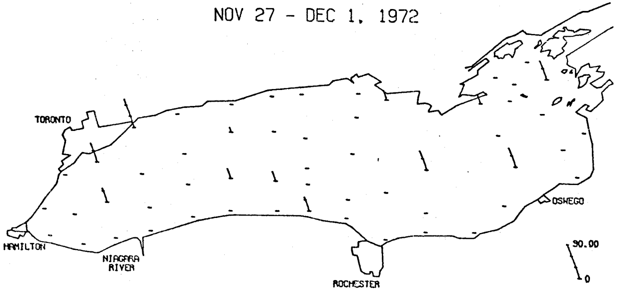
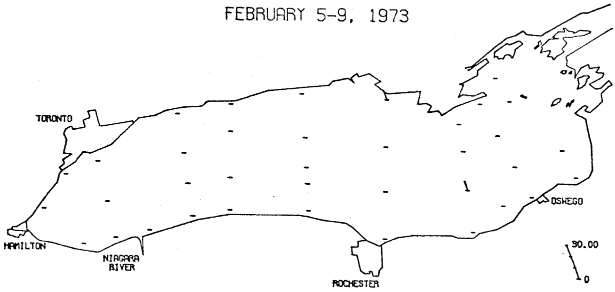


FIG. 41 continued.



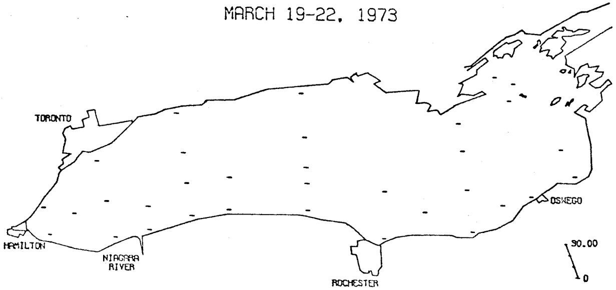
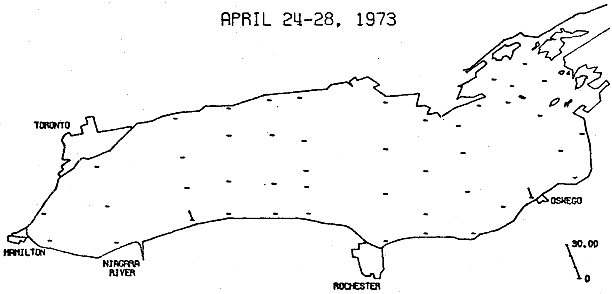


FIG. 41 continued.



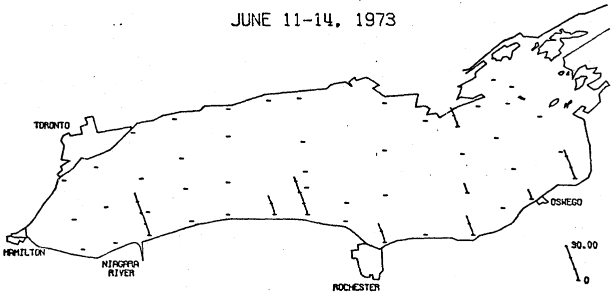


FIG. 41 continued.

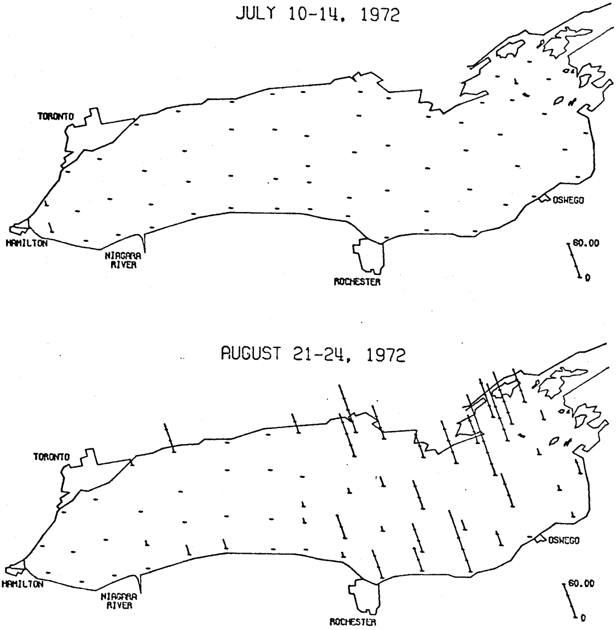
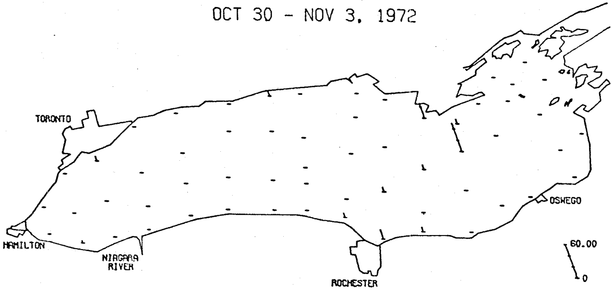


FIG. 42. Distribution of *Scenedesmus quadricauda* var. *quadrispina*.



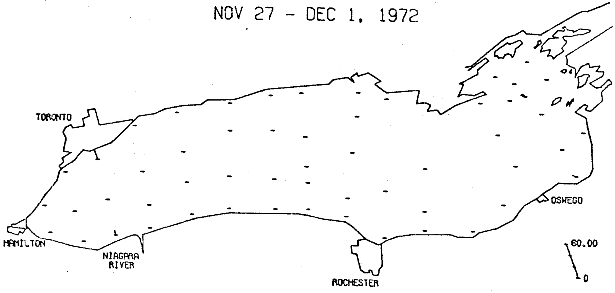


FIG. 42 continued.

eastern half of the lake and at several nearshore stations in the western half. These populations were considerably reduced by October, and only isolated occurrences at stations near Toronto and Niagara were noted in November. No occurrences of this taxon were noted in months sampled subsequently.

Ulothrix spp. (Fig. 43). The dominant population included in this category is *U. subconstricta* G. S. West (194 occurrences) although counts of two entities of uncertain taxonomic affinities (one with 63 occurrences and the other with 2) and a single record of *U. tenerrima* Kütz. have been included.

Records of this genus in the phytoplankton of the Great Lakes are very incomplete, but personal observations indicate that high population densities are largely restricted to eutrophied regions. Nalewajko (1966) has recorded relatively low-level populations from Lake Ontario, although other authors do not record it among the more abundant forms in the phytoplankton.

In the light of our results this is rather surprising. A few high levels of occurrence were recorded from samples taken during May 1972, but by June it was present in considerable quantities at most stations in the northern half of the lake and at several nearshore stations in the southern half. These populations apparently declined substantially by the time the July samples were taken, although substantial populations were still present at stations 8 and 19 near Toronto. Abundance of *Ulothrix* spp. increased again in August, particularly in the eastern and southern part of the lake. Extremely high population density was noted at station 60 near Rochester. Population densities declined in October and this trend continued through November, reaching the yearly low in February 1973. Samples from the March cruise showed slightly increased population densities of *Ulothrix*, but no further increase was evident in samples taken during April 1973. Populations did increase substantially in July but never approached the levels or the wide distribution noted in June 1972.

Cyanophyta

Anabaena flos-aquae (Lyngb.) Bréb. (Fig. 44). Occasional low-level populations of this species are found throughout the Laurentian Great Lakes, but abundant occurrences seem to be restricted to areas which have undergone some degree of eutrophication. It is one of the species which has become much more abundant in Lake Michigan in recent years although it was recorded as rare in earlier collections (Ahlstrom 1936). In Lake Ontario it was recorded from Irondequoit Bay (Tessler et al. 1953), and other records for the genus from the Bay of Quinte (Michalski 1968) and stations in the open lake (Nalewajko 1966) probably refer, in part, to this taxon. Ogawa (1969) found it to be abundant at a number of open lake stations sampled during September 1964. This species is capable of

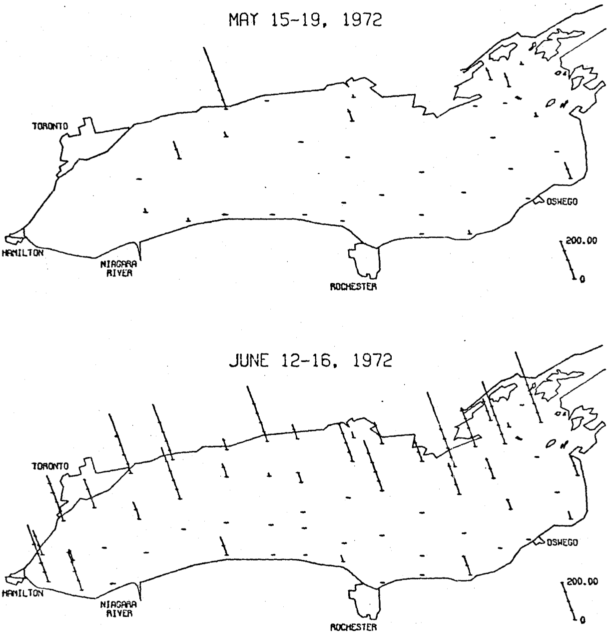
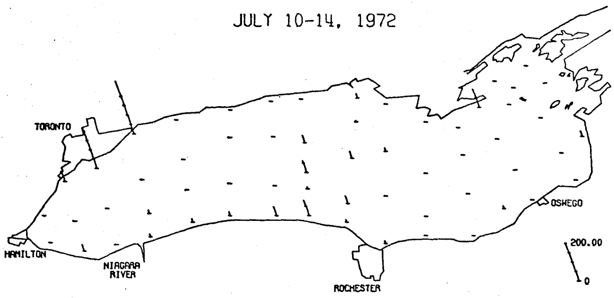


FIG. 43. Distribution of *Ulothrix* spp.



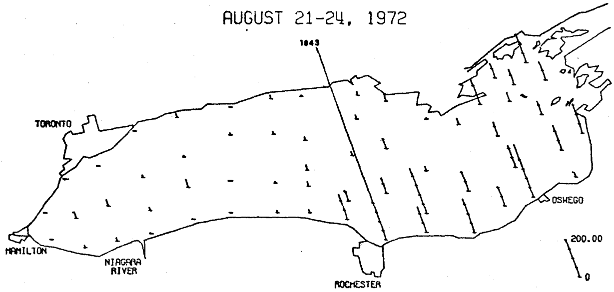


FIG. 43 continued.

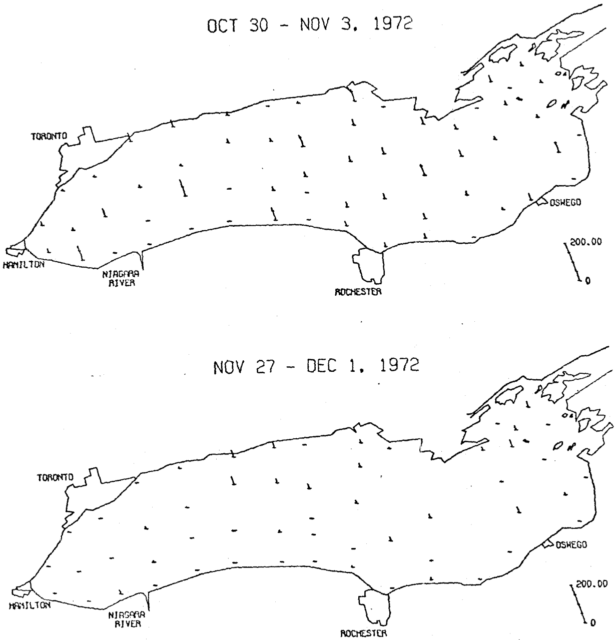


FIG. 43 continued.

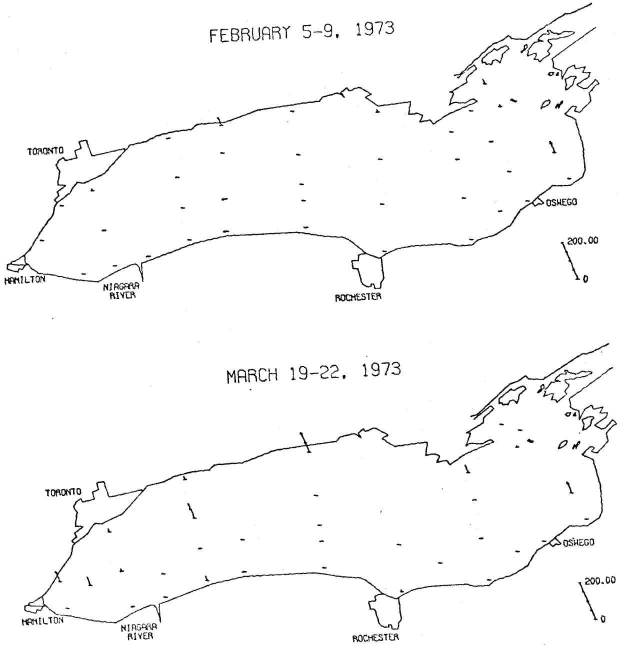
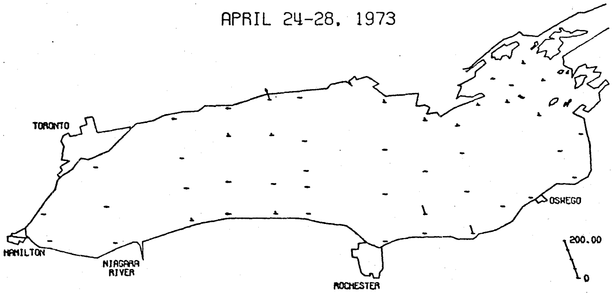


FIG. 43 continued.



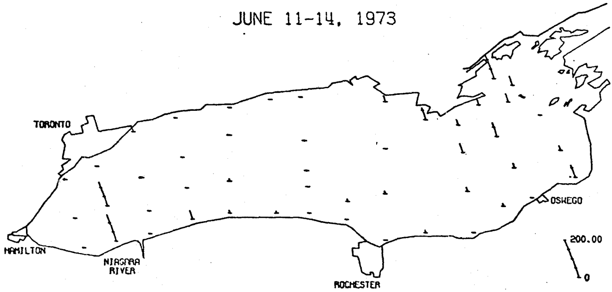
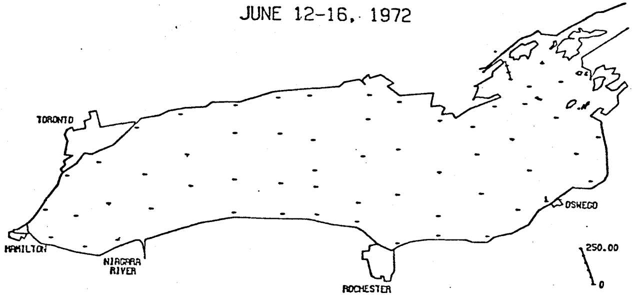


FIG. 43 continued.

JUNE 12-16, 1972



JULY 10-14, 1972

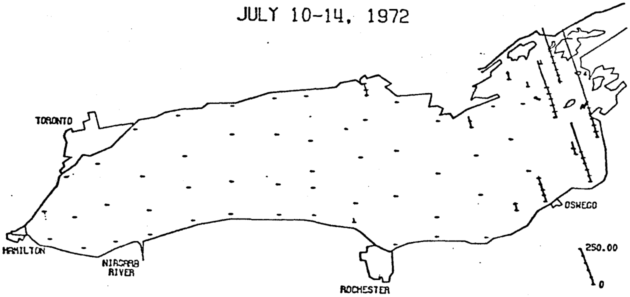
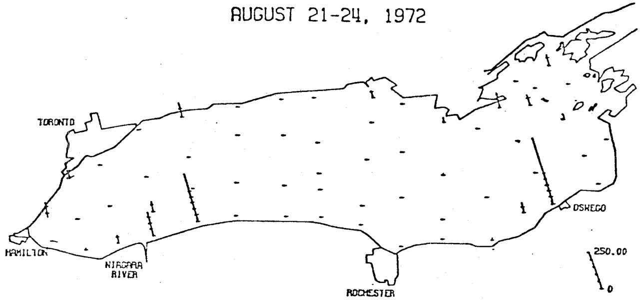


FIG. 44. Distribution of *Anabaena flos-aquae*.



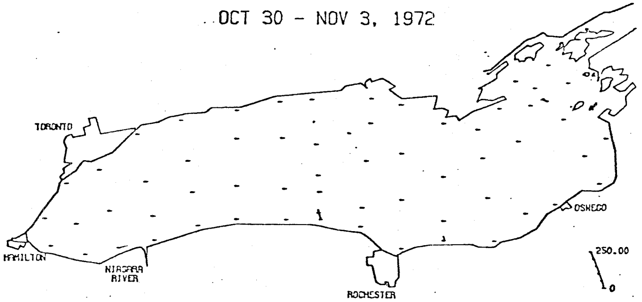


FIG. 44 continued.

producing obnoxious water blooms and is one of the taxa contributing to such nusiances in western Lake Erie (Ogawa and Carr 1969). On the basis of Ogawa and Carr's study, it would appear that this species is also one of those capable of fixing nitrogen under conditions where excessive phosphorus input led to depletion of available nitrogen in the system.

This species was not noted in samples from the May 1972 cruise, and only a few isolated populations were noted in the June samples. It was found in considerable abundance at a number of stations in the eastern part of the lake during July. In August it was particularly abundant at station 90 near Oswego and at several stations near Niagara. Somewhat smaller population densities were noted at several stations in the eastern part of the lake and at isolated nearshore stations along the northern shore. Only a few isolated populations were found in samples from the October cruise, and this species was not recorded from any of the subsequent cruises.

Anabaena variabilis Kütz. (Fig. 45). The identity of this small species of *Anabaena* is somewhat questionable. Although it is apparently very widely distributed in both fresh and saline water (Huber-Pestalozzi 1938), previous records from the Laurentian Great Lakes are lacking. It forms gas vacuoles and may contribute to water blooms, and Ogawa and Carr (1969) have demonstrated that laboratory strains of this species are capable of fixing nitrogen.

A single isolated population was noted in collections taken during the May 1972 cruise, but it was not noted in June and July. In August, however, high population densities of this species were noted at a number of stations in the southern half of the lake and less abundant occurrences at several stations nearest the northern shore. A few isolated occurrences were found in samples from the October and November 1972 cruises and February 1973 cruises. This species was not found in samples from the March and April cruises but it did occur at a few stations in the eastern half of the lake during June 1973.

Anacystis cyanea Dr. and Daily (Fig. 46). This species is one of the blue-green algae capable of forming nusiance-producing water blooms. It is present in many highly eutrophied areas in the Great Lakes, but reliable quantitative estimates of its abundance are not common. This is partially because it tends to occur in ephemeral blooms and the cells usually are contained in large colonies, which renders obtaining accurate estimates of its abundance very difficult.

Like most bloom forming species of blue-green algae, *A. cyanea* usually reaches its peak abundance during the warmest months of the year. In this respect, its seasonal distribution in Lake Ontario during the IFYGL sampling period is highly unusual. In May 1972 a single isolated population was noted at station 90 near Oswego. In June somewhat higher

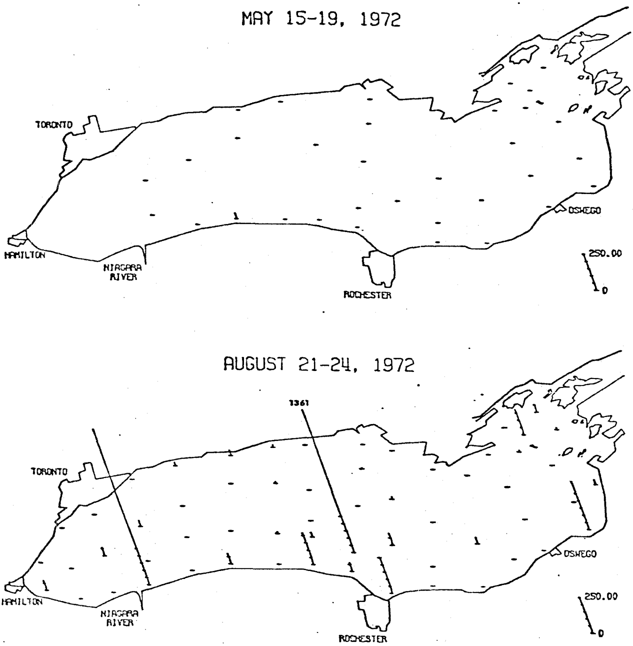
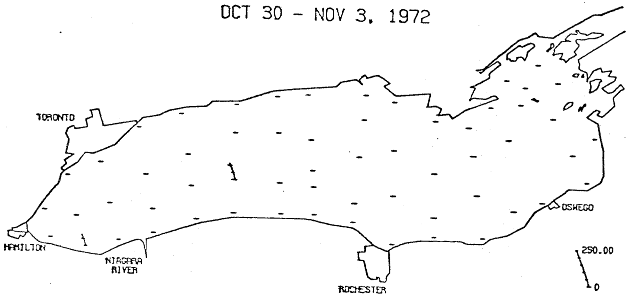


FIG. 45. Distribution of *Anabaena variabilis*.



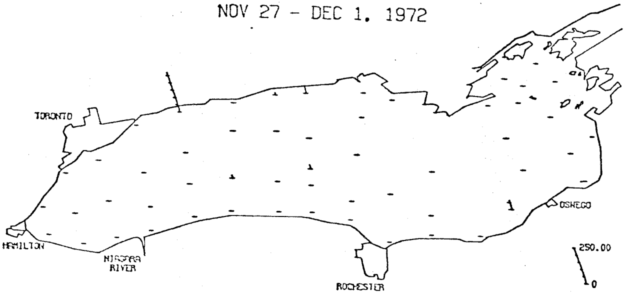
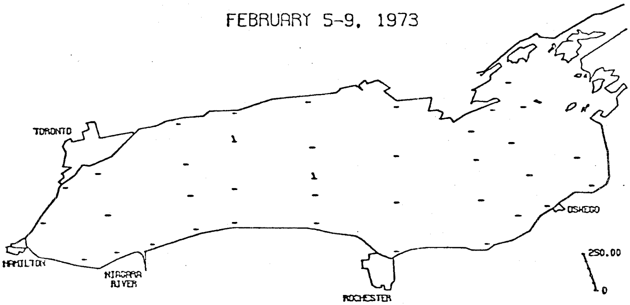


FIG. 45 continued.



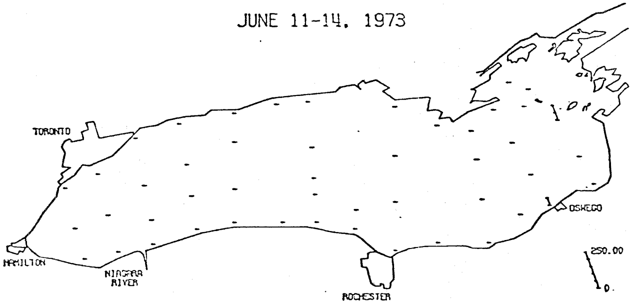


FIG. 45 continued.

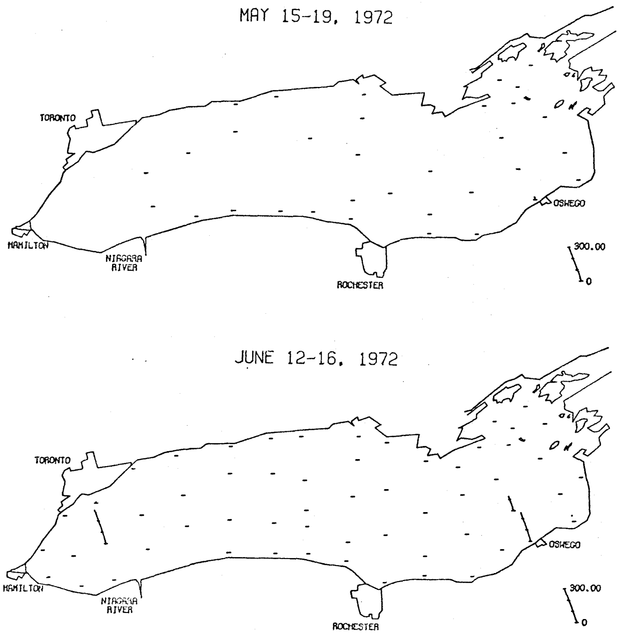
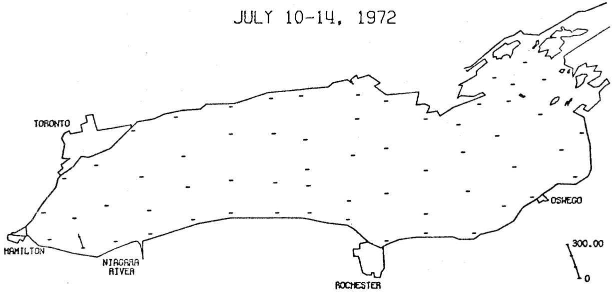


FIG. 46. Distribution of *Anacystis cyanea*.



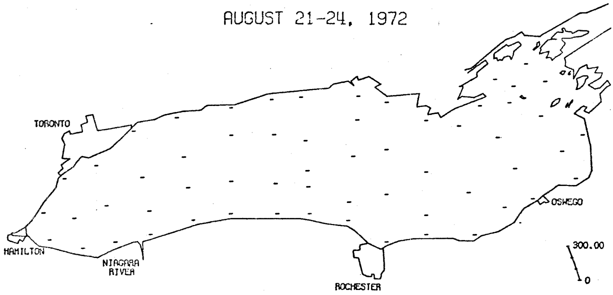
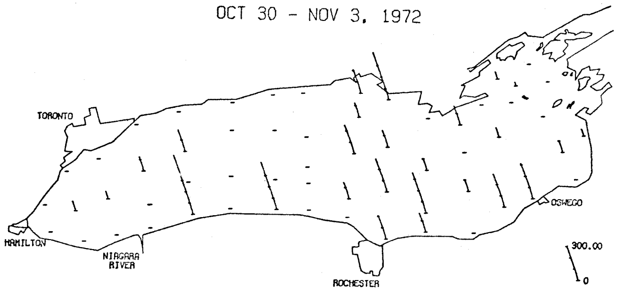


FIG. 46 continued.



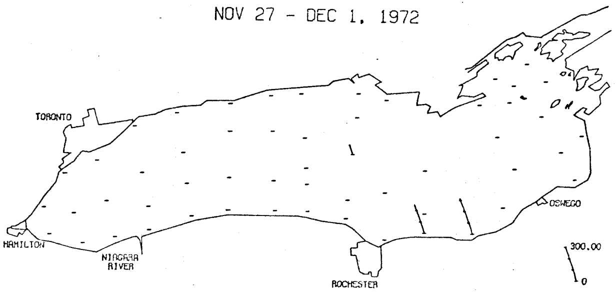
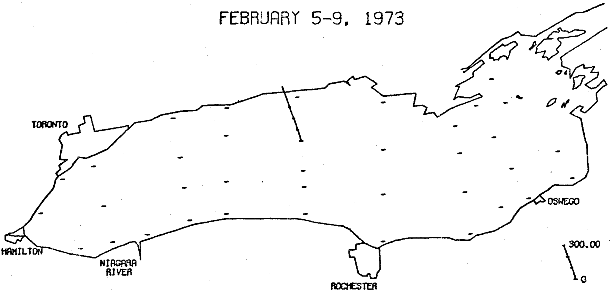


FIG. 46 continued.



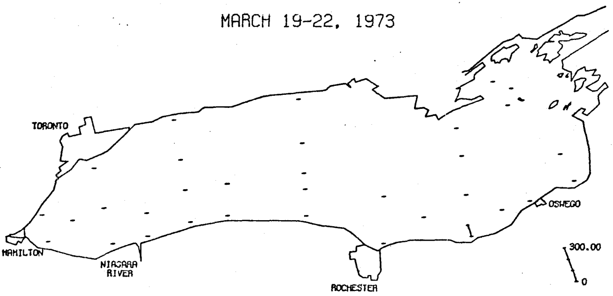
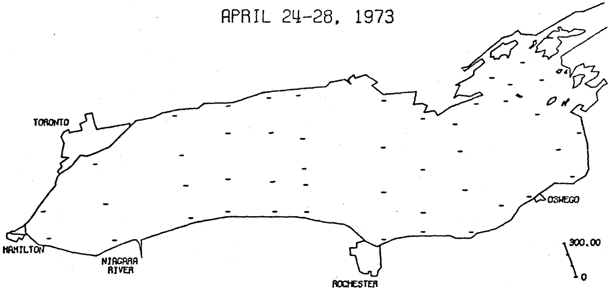


FIG. 46 continued.



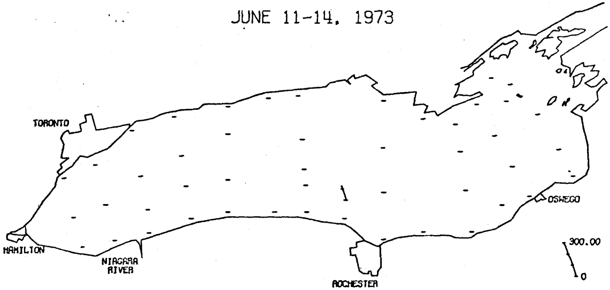


FIG. 46 continued.

populations were noted at the same station, at station 85 adjacent to it, and at station 10 in the far end of the lake. In July a single population was detected at station 3, and in August, when population densities might be expected to be relatively high, this species was not noted in any of our samples. In October, however, high population densities of *A. cyanea* were noted at a number of stations. By November populations had declined except at stations 72 and 73, east of Rochester. Only single isolated populations were noted during February, March, and June sampling periods in 1973.

Anacystis incerta Dr. and Daily (Fig. 47). This small species contains gas vacuoles and, according to Drouet and Daily (1956), may form blooms. It is, however, rarely associated with nuisance conditions in the Great Lakes. Unlike many other species of blue-green algae in the Great Lakes it tends to reach peak abundance during cooler months of the year, especially during the fall cooling period. In reviewing the records of its occurrence available to us, it would appear that it is most successful under conditions where silica depletion limits diatom growth.

In Lake Ontario during the IFYGL field sampling period it was abundant at stations in the eastern part of the lake in May, with only isolated low-level populations being detected at other stations. During the June sampling cruise, conversely, sizable populations were found only at stations in the far western part of the lake with a few low-level occurrences at mid-lake stations and in Mexico Bay. Populations dropped to very low levels during the July sampling period, but a few isolated abundant occurrences were noted at widely separated stations during August 1972. Only occasional occurrences were noted during the rest of the months sampled, and it did not return to the levels of abundance noted the previous spring.

Aphanizomenon flos-aquae (L.) Ralfs (Fig. 48). This species is capable of causing extreme nuisances under bloom conditions. Its distribution in the Laurentian Great Lakes is largely restricted to highly eutrophied areas. Although it is a conspicuous element of net collections from such areas, estimates of its abundance made by standard phytoplankton counting methods are subject to large uncertainties because of its growth habit. It has been reported as being abundant in Irondequoit Bay (Tressler et al. 1953) and the Bay of Quinte (McCombie 1967; Michalski 1968) but, although it is visibly present in the surface waters of some regions of Lake Ontario proper, it has not often been reported from stations in the open lake. Ogawa (1969), however, found it to be abundant at a number of stations sampled in September 1964.

In our collections a single occurrence was noted at station 105 in Mexico Bay during June 1972, and relatively high abundance of this species was noted at this station and a few others in the eastern part of the lake during August. Scattered populations were also noted in samples taken during October, but this species was apparently absent from subsequent samples.

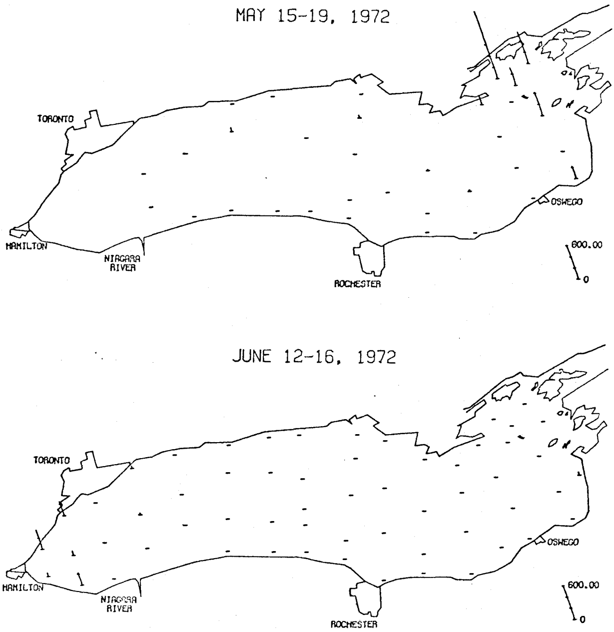
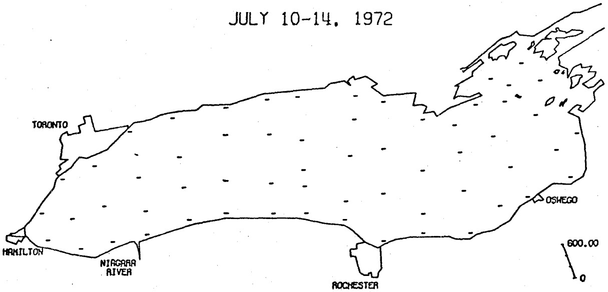


FIG. 47. Distribution of *Anacystis incerta*.



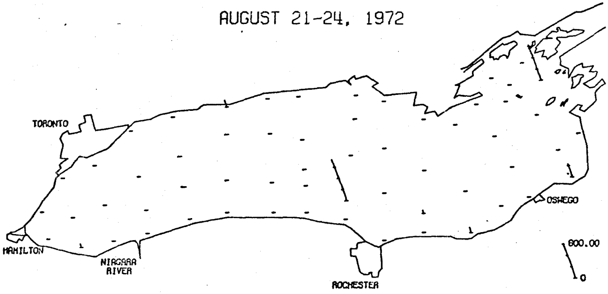
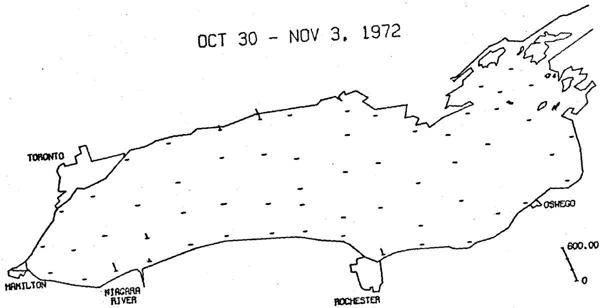


FIG. 47 continued.



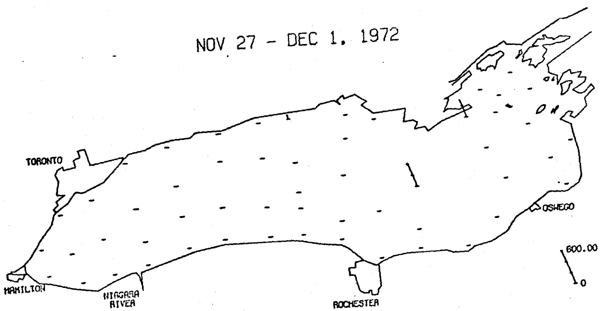
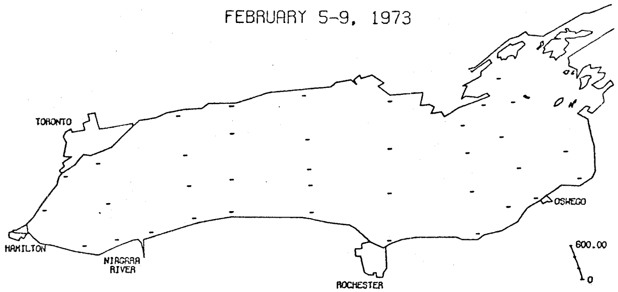


FIG. 47 continued.



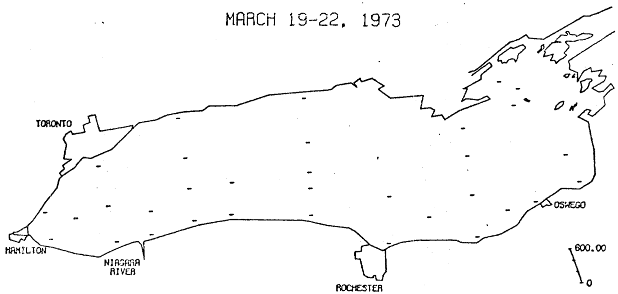


FIG. 47 continued.

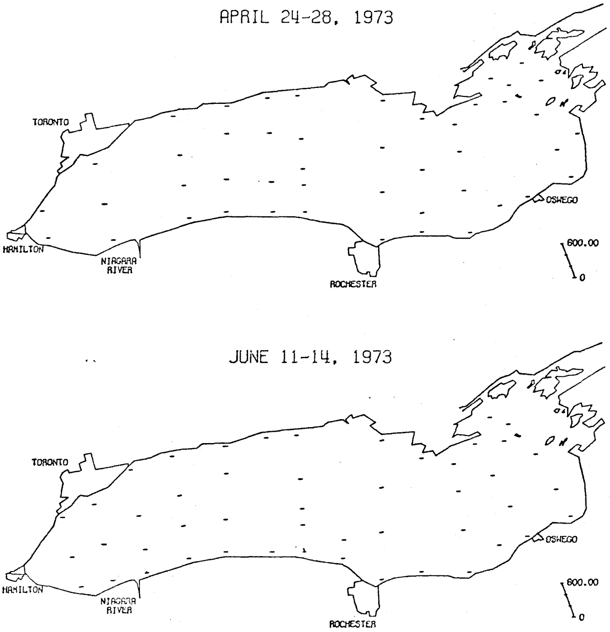


FIG. 47 continued.

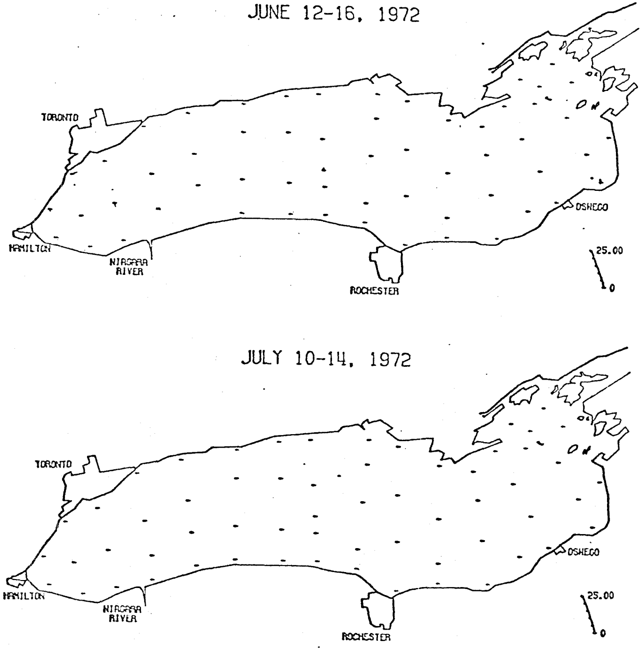
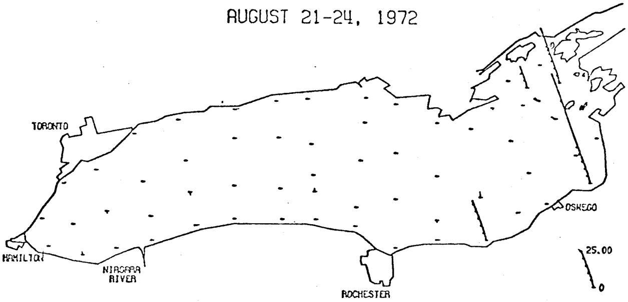


FIG. 48. Distribution of *Aphanizomenon flos-aquae*.



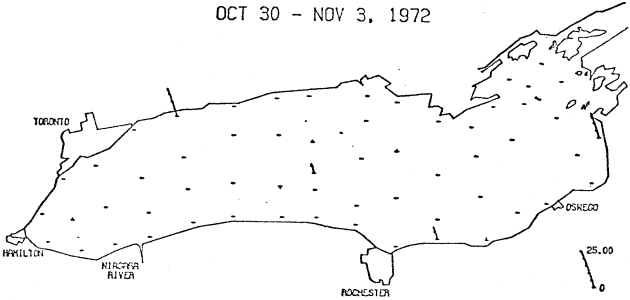


FIG. 48 continued.

Gomphosphaeria aponina Kütz. (Fig. 49). According to Huber-Pestalozzi (1938) this species is a facultatively planktonic form which is widely distributed in large and small lakes and also occasionally occurs in brackish water. Although records are insufficient to assess its general distribution in the Laurentian Great Lakes, it has been reported from western Lake Erie (Taft and Taft 1971) and we have observed occasional populations in Lake Michigan.

The occurrence of *G. aponina* in Lake Ontario during the IFYGL sampling period was strikingly limited. It was noted only in samples from the October 1972 cruise when relatively high population densities were noted at several stations in the eastern part of the lake.

Gomphosphaeria lacustris Chodat (Fig. 50). This very common and widely distributed member of the genus is found throughout the Laurentian Great Lakes and is often one of the more abundant species of the sparse summer plankton of the upper lakes. Although it was recorded from stations in Lake Ontario collected in September 1964 by Ogawa (1969), it was not reported in more recent surveys.

In our collections, a single population was noted from samples collected during May 1972. It was not found in samples taken during June and July, but was relatively abundant at scattered stations collected during August. Similar occurrences were found in October, but it was absent from collections taken on subsequent cruises until June 1973, when a few isolated populations were again collected.

Gomphosphaeria wichurae Dr. and Daily (Fig. 51). According to Drouet and Daily (1956), this species often forms conspicuous blooms during the warmer months of the year in freshwater lakes. Partially because of the confusion that surrounds the taxonomy of this species, previous records of its occurrence in Lake Ontario and the other Great Lakes are difficult to determine. It would appear, however, that it is usually associated with eutrophic conditions and is potentially a nuisance-producing form.

In our samples, only isolated low-level populations were detected during May through August 1972. In October, however, large populations were noted at most offshore stations in the northwestern sector of the lake and at a few stations in other regions. Although populations were somewhat reduced in samples from the November cruise, they were again noted at many stations, primarily in the western portion of the lake. A few stations sampled during February 1973 still contained significant levels of this species, but it continued to decline in abundance and only isolated occurrences were noted in March and April. It was not noted in our June 1973 samples.

Oscillatoria limnetica Lemm. (Fig. 52). This species is by far the

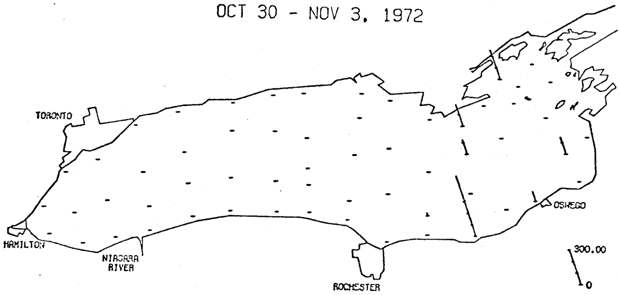


FIG. 49. Distribution of *Gomphosphaeria aponina*.

most common member of the genus in our collections. According to Huber-Pestalozzi (1938) it is a common euplanktonic form which often occurs in polluted water. It apparently has not been widely reported from the Great Lakes, although Munawar and Nauwerck (1971) record it as being an abundant form in the fall plankton of Lake Ontario, and Nalewajko (1966) lists several occurrences of the very similar *O. planktonica* Wol., also from Lake Ontario.

Relatively small populations of this species were noted in our collections from the May 1972 cruise. In June, however, it was one of the dominant species at many stations in the northern part of the lake. The very abundant populations noted the previous month had declined by July, although there was one particularly high abundance occurrence noted at station 19 near Toronto, and the species was quite uniformly distributed throughout the lake. There was, however, a trend towards lower population densities at offshore stations in the southern half of the lake, a pattern which was repeated by several other taxa. Relatively low population densities were noted at stations sampled during August, with a tendency for highest abundance to occur at stations along the southern shore. Population densities were also low during October, but populations seemed to be evenly distributed

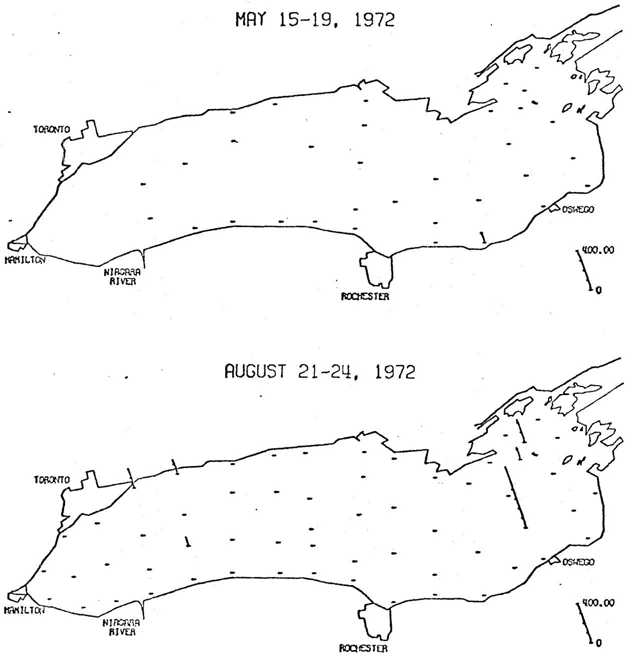
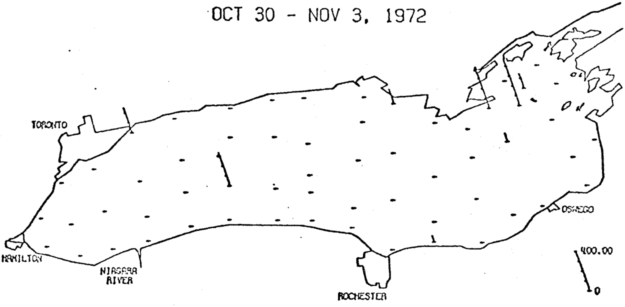


FIG. 50. Distribution of *Gomphosphaeria lacustris*.



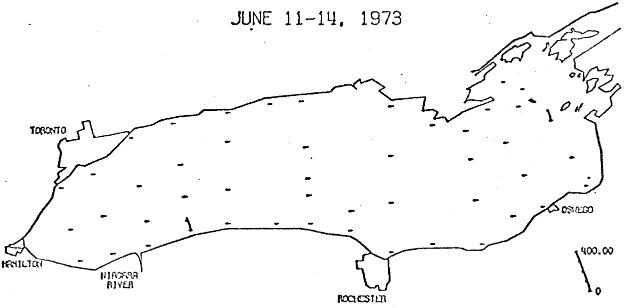


FIG. 50 continued.

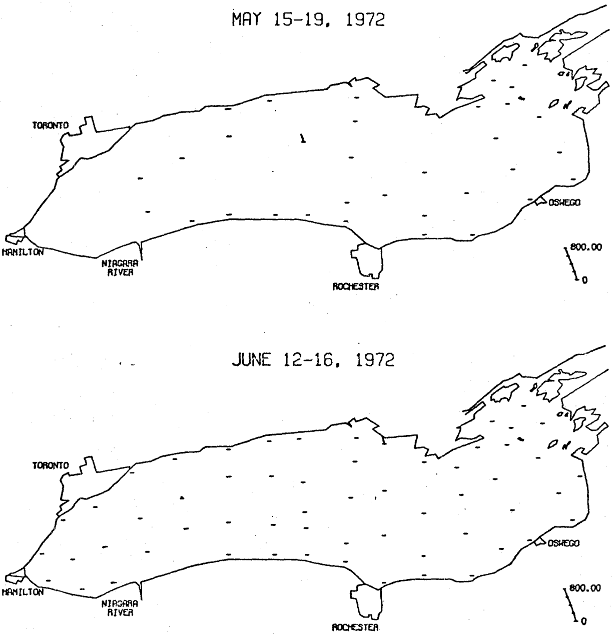
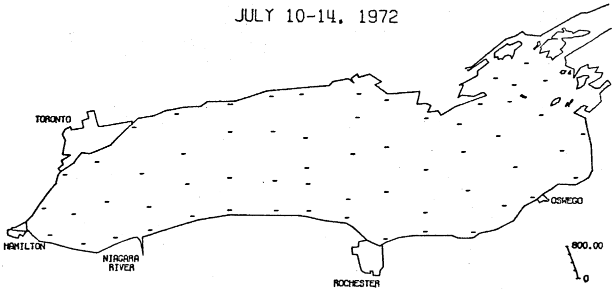


FIG. 51. Distribution of *Gomphosphaeria wichurae*.



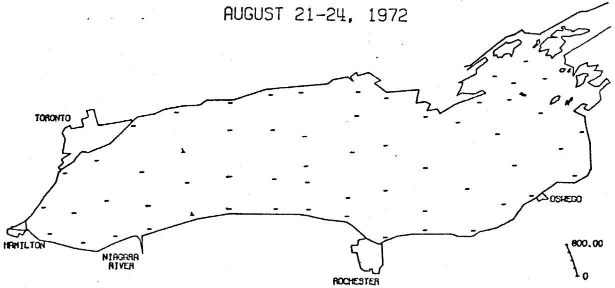
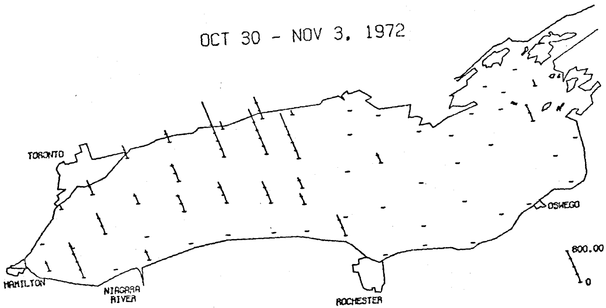


FIG. 51 continued.



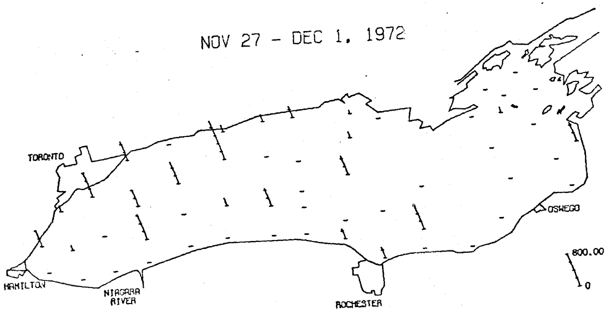
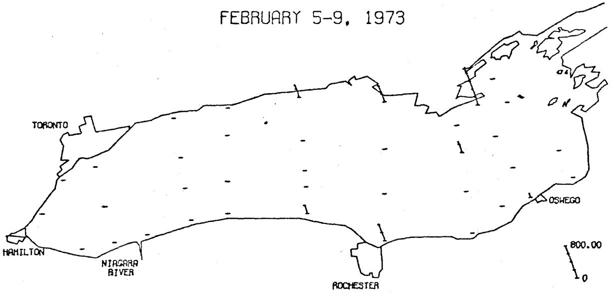


FIG. 51 continued.



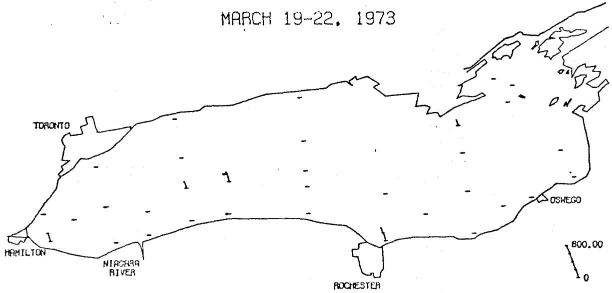
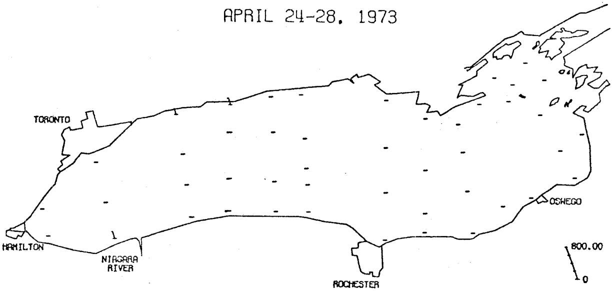


FIG. 51 continued.



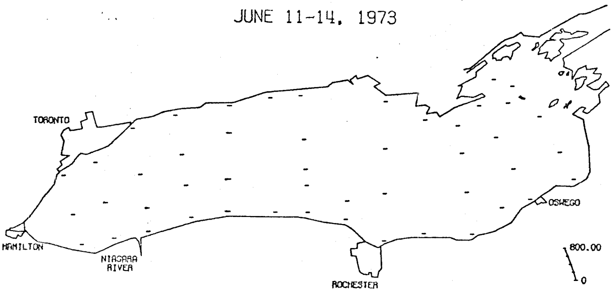


FIG. 51 continued.

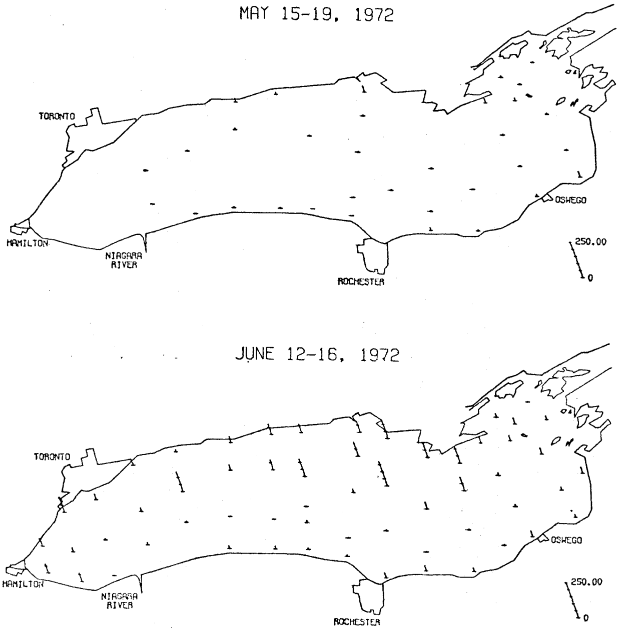
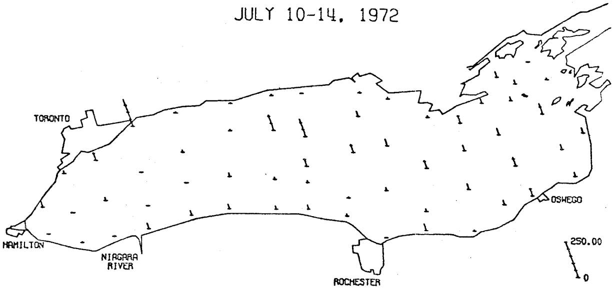


FIG. 52. Distribution of *Oscillatoria limnetica*.



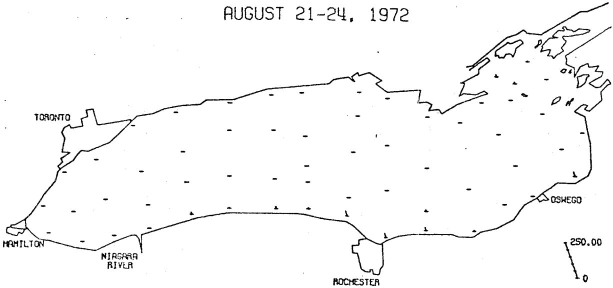


FIG. 52 continued.

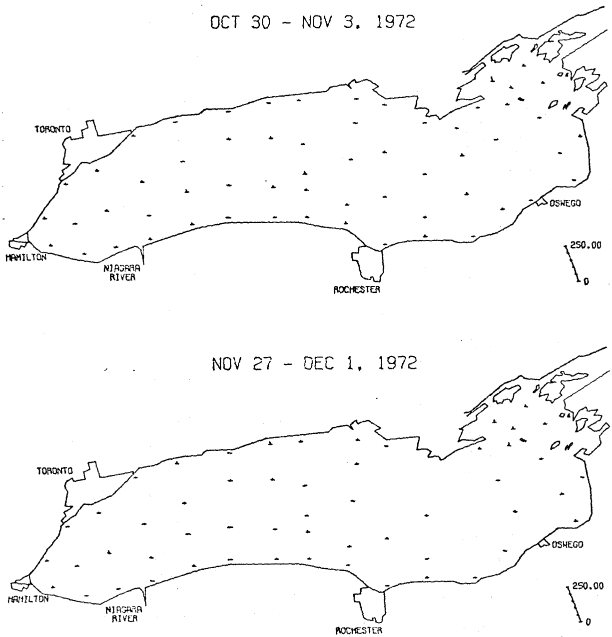
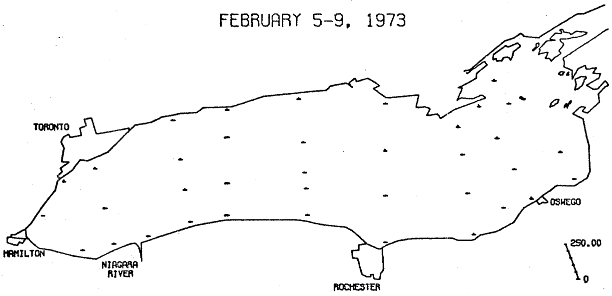


FIG. 52 continued.



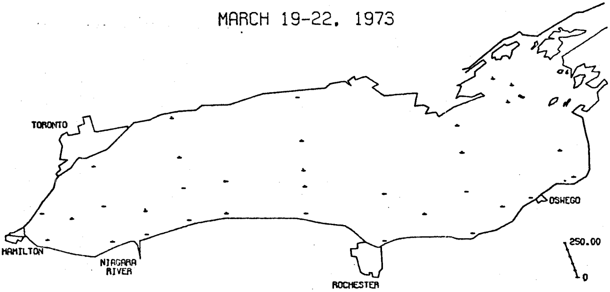
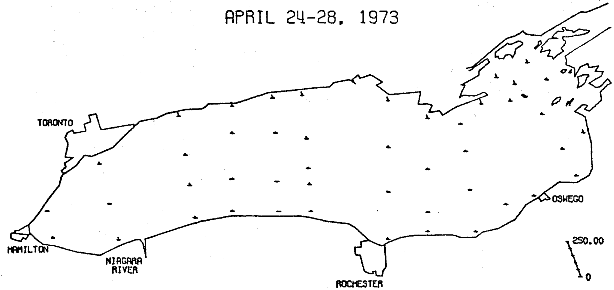


FIG. 52 continued.



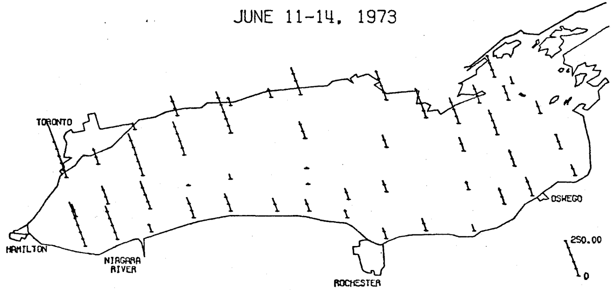


FIG. 52 continued.

throughout the lake. Approximately the same situation was evident from samples taken on the November 1972 and February and March 1973 cruises. Slightly increased population densities of *O. limnetica* were noted in April samples from stations along the northern shore and in the north-eastern part of the lake. A marked increase in the abundance of this species was noted in most samples from the June 1973 cruise, although significantly lower values were recorded from a cluster of stations (26, 32, 44, and 45) near the mid-region of the lake.

Cryptophyta

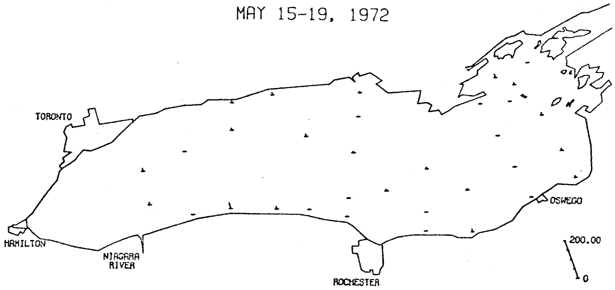
Cryptomonas erosa Ehr. (Fig. 53). This large member of the genus is widely distributed in the Great Lakes, usually, however, in relatively low numbers. According to Huber-Pestalozzi (1968) it is a eurytopic organism, occurring both in oligotrophic lakes and often, in abundance, in eutrophic and slightly saline habitats. According to Munawar and Nauwerck (1971) it was present in all seasons in Lake Ontario during 1970, with greatest abundance in the spring and fall.

In our samples, appreciable populations were present at most stations sampled during May 1972. By June very large populations had developed in the eastern part of the lake, particularly at nearshore stations on the southern shore. By July these populations had collapsed, and numbers of *C. erosa* remained low throughout the remainder of 1972. It should be noted that a few examples of it were found at most stations sampled, but usually in such low numbers that they are completely insignificant when scaled against the high populations found in June. In samples taken during February 1973, appreciable populations of this species occurred at many of the stations sampled, and slight increases were noted in samples taken during the March and April cruises. These populations, however, never approached the densities found the previous year and, contrary to the situation the previous year, had declined significantly by the time the June samples were taken.

Pyrrophyta

Glenodinium and *Gymnodinium* spp. (Fig. 54). This composite category includes the smaller species of these two genera which could not be identified satisfactorily in our collections. Such species are usually a minor component of the offshore phytoplankton of the Laurentian Great Lakes. Munawar and Nauwerck (1971) have indicated that these organisms are an appreciable part of the Lake Ontario phytoplankton in the summer and fall.

Relatively high levels of occurrence were noted at numerous stations throughout the lake in our May 1972 samples. Levels of abundance declined somewhat by June, although occurrences were still noted at most stations and relatively high population densities were present at a few of the stations sampled. Population densities increased again in July,



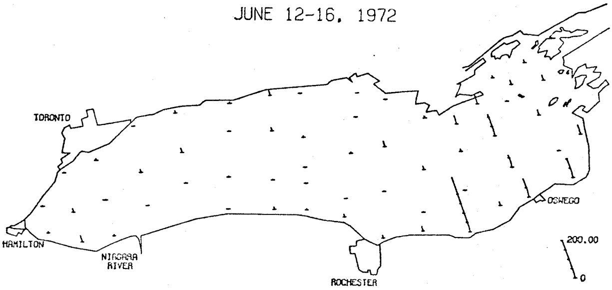


FIG. 53. Distribution of *Cryptomonas erosa*.

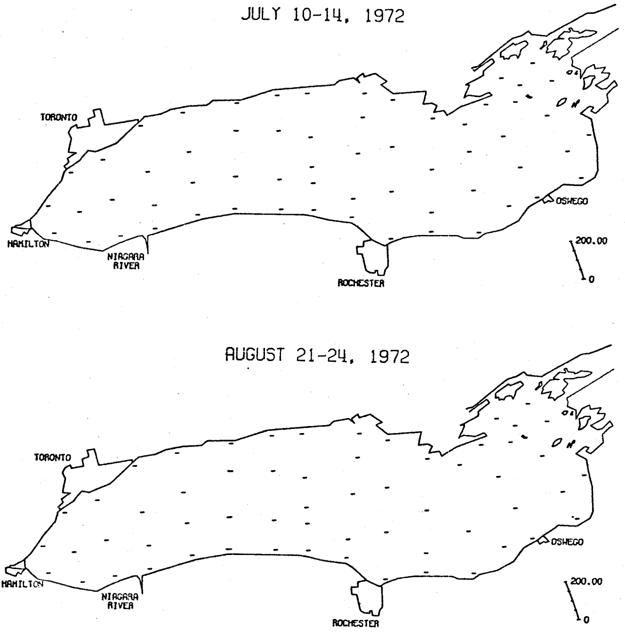
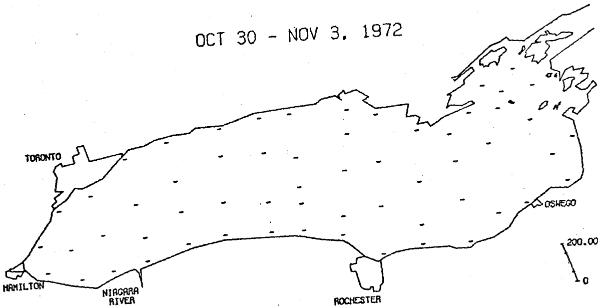


FIG. 53 continued.



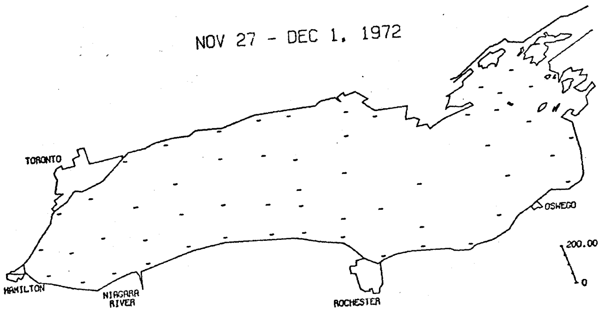
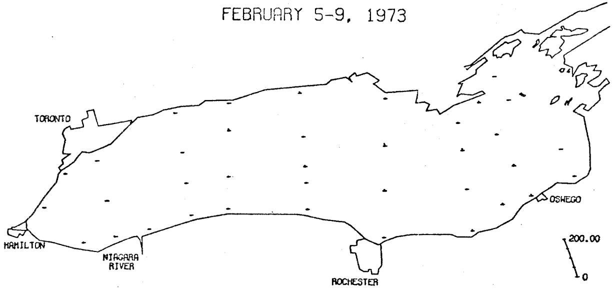


FIG. 53 continued.

FEBRUARY 5-9, 1973



MARCH 19-22, 1973

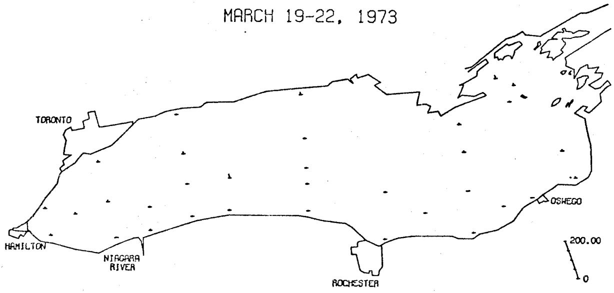
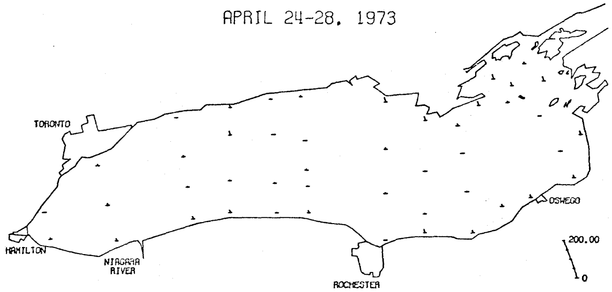


FIG. 53 continued.



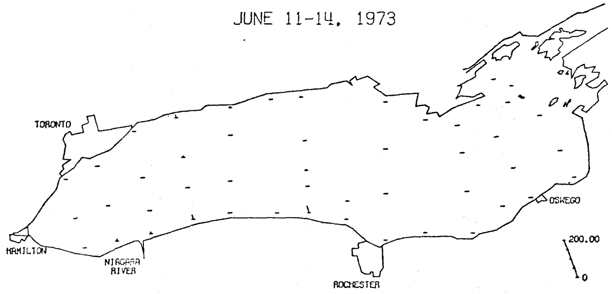
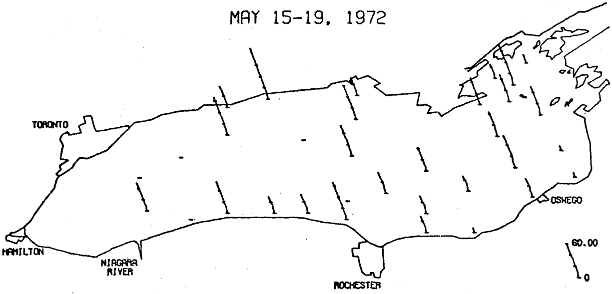


FIG. 53 continued.

MAY 15-19, 1972



JUNE 12-16, 1972

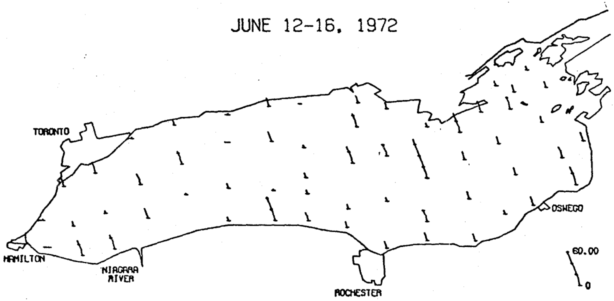


FIG. 54. Distribution of *Glenodinium* and *Gymnodinium*.

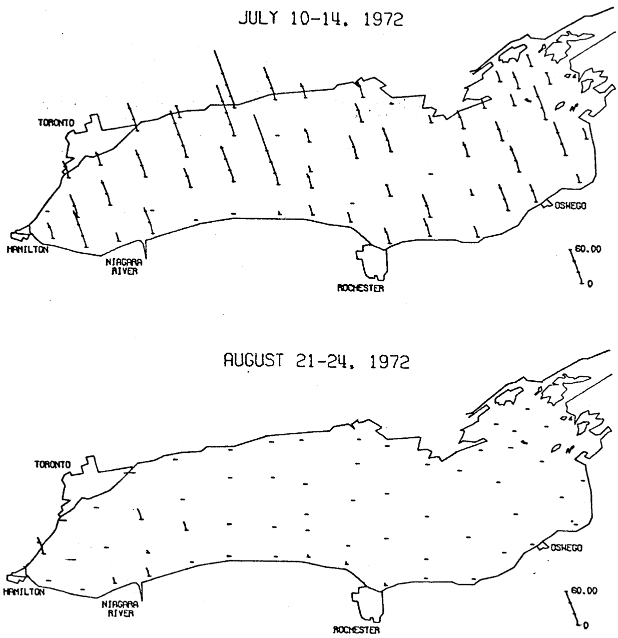
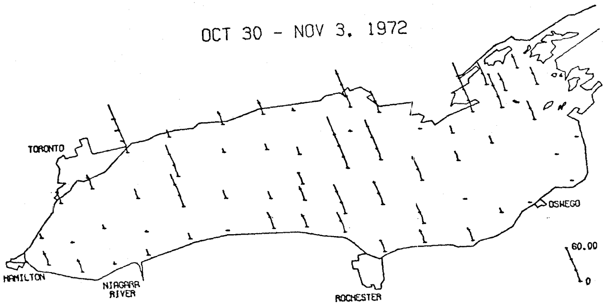


FIG. 54 continued.



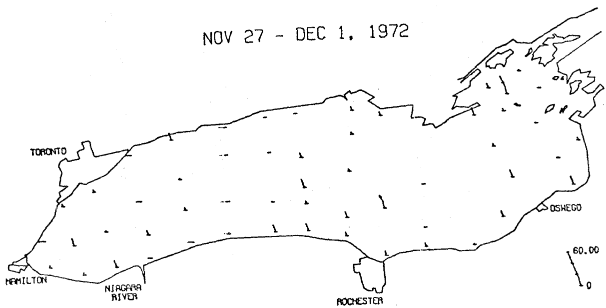
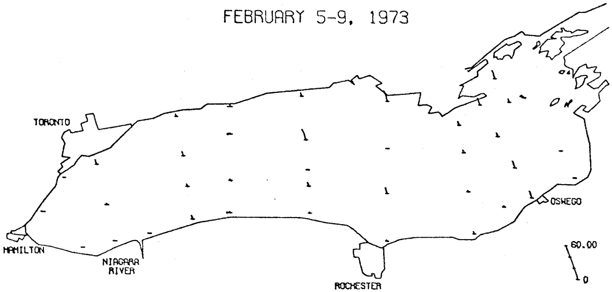


FIG. 54 continued.



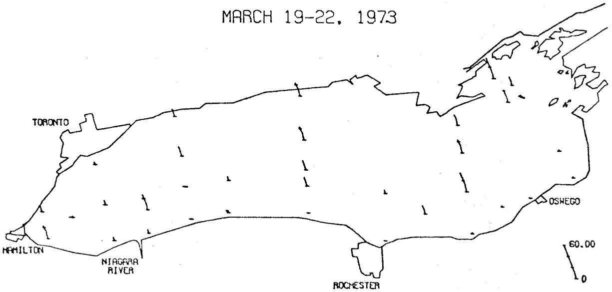
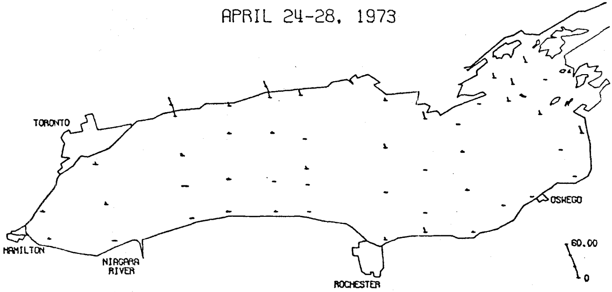


FIG. 54 continued.

APRIL 24-28, 1973



JUNE 11-14, 1973

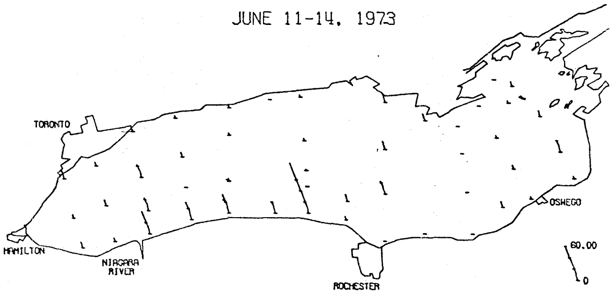


FIG. 54 continued.

particularly at stations in the western half of the lake, although very low abundance was found at certain nearshore stations there. These populations had apparently crashed by the time the August samples were taken, as only isolated low-level occurrences were noted at stations in the western part of the lake and along the southern shore. A considerable increase was noted at most stations sampled during October, however levels of abundance had declined again by the time the November 1972 samples were taken. Population densities remained low during February, however they increased slightly in our March samples despite a reduction in total phytoplankton abundance. The populations apparently declined again, and only low levels of abundance were noted in our April samples, with highest occurrences at stations nearest shore and in the eastern part of the lake. Samples from the June 1973 cruise showed high abundance of these organisms at stations along the southeastern shore, but abundance levels never reached those noted the previous spring.

Peridinium spp. (Fig. 55). Members of this genus are usually present, though not in great abundance, in phytoplankton samples from the offshore waters of the Laurentian Great Lakes. The taxonomy of species occurring in the Great Lakes is poorly known, and we were not able to achieve satisfactory determinations of the entities in our samples, although more than one population is probably involved. Previous records of the distribution of this genus in Lake Ontario are essentially lacking, although our data indicate that its members contribute a significant portion of the total phytoplankton at certain stations during some seasons of the year.

In our samples from the May 1972 cruise, *Peridinium* was relatively abundant at stations nearest the southern shore and stations in the eastern part of the lake. By the time the June samples were taken, these populations had apparently declined and significant population densities were noted only at a few mid-lake stations. A similar situation was noted in July, although at this time high population densities were more common in the central region of the lake rather than at offshore stations in the east and west, as they had been the previous month. Population densities of *Peridinium* increased again in August, particularly at stations near shore in the northern and eastern parts of the lake. These populations had declined significantly by October and only scattered, low-level populations were noted. Populations remained low in samples from the November 1972 cruise, although slight increases were noted at stations in the western half of the lake. Only scattered, low-level occurrences were found in February 1973 samples, and only slight increases in abundance in samples from the March cruise. Population densities again increased at nearshore stations during April and at stations throughout the lake in June 1973, but never reached the levels noted the previous spring.

Microflagellates (Fig. 56)

We have included in this category all flagellated unicellular forms less

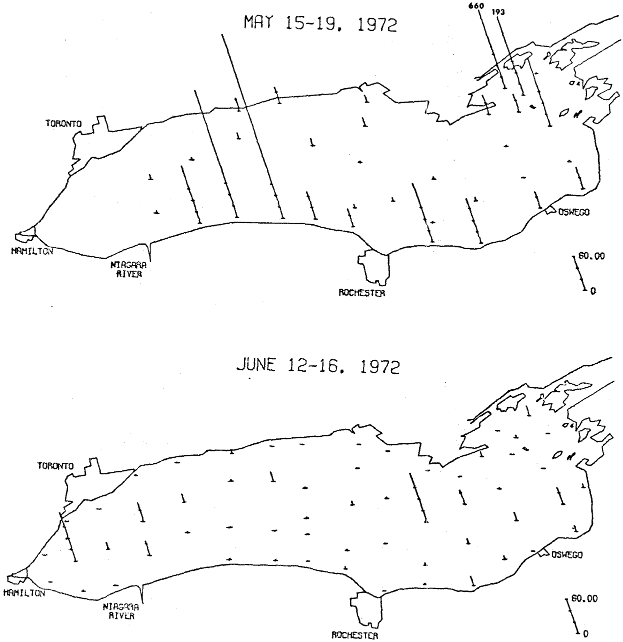
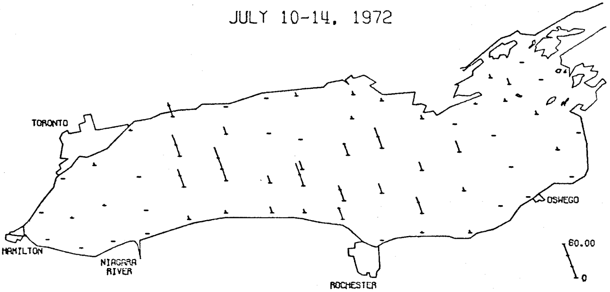


FIG. 55. Distribution of *Peridinium* spp.



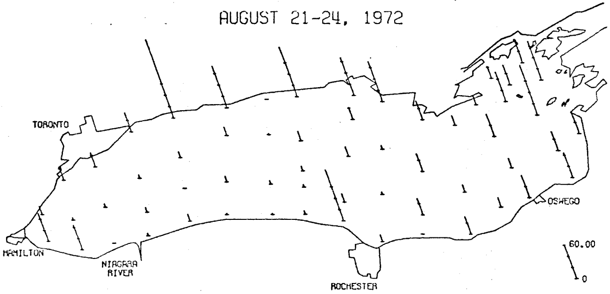
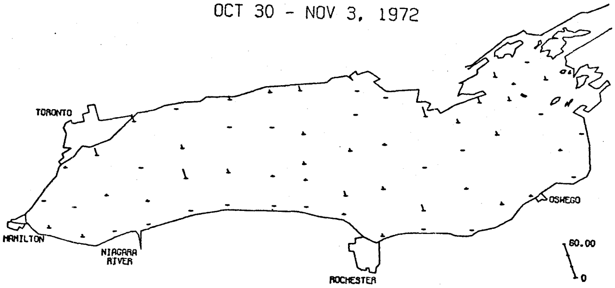


FIG. 55 continued.



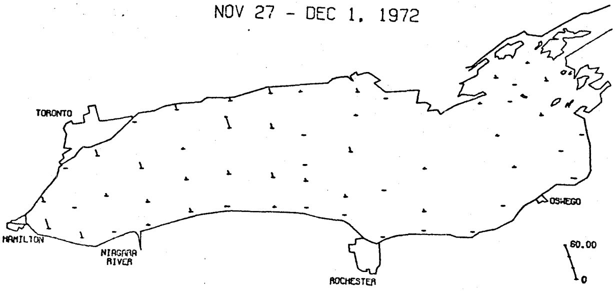


FIG. 55 continued.

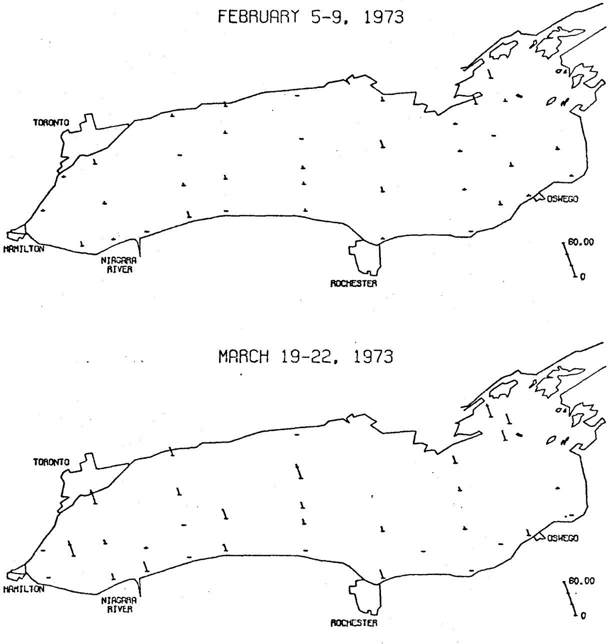


FIG. 55 continued.

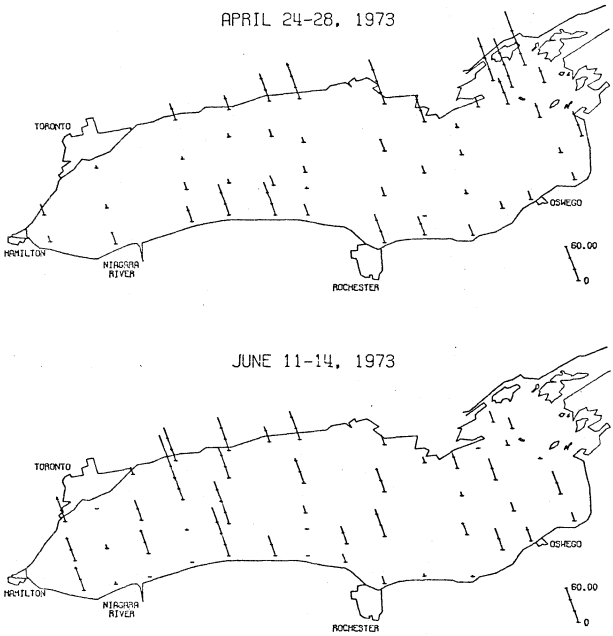


FIG. 55 continued.

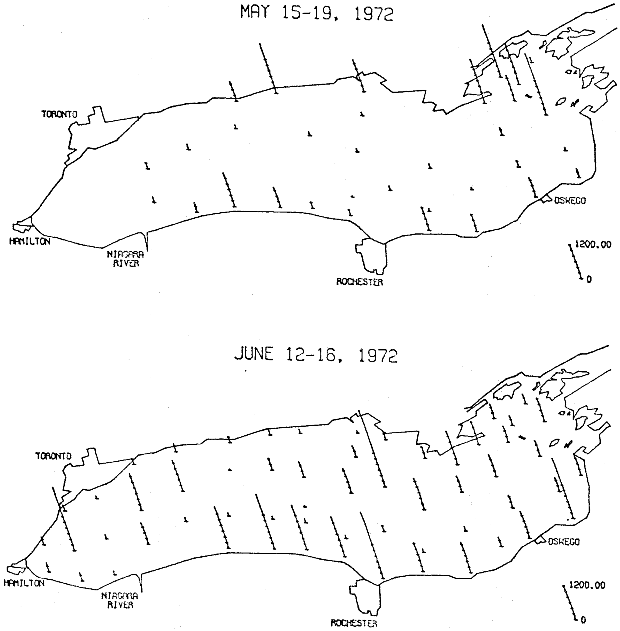
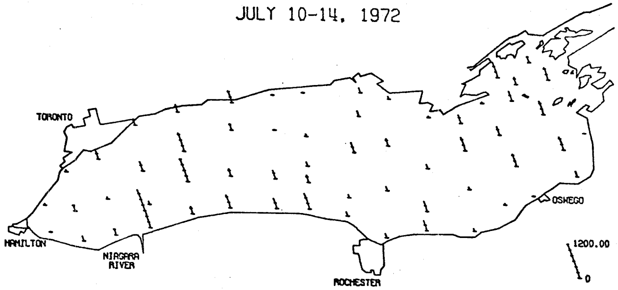


FIG. 56. Distribution of microflagellates.



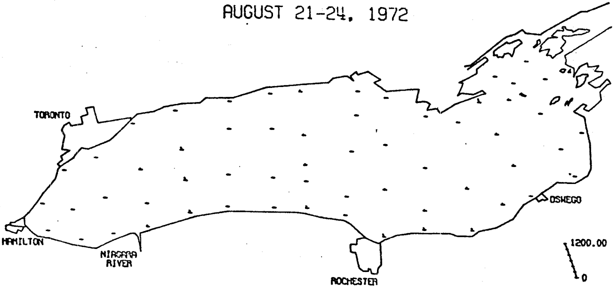
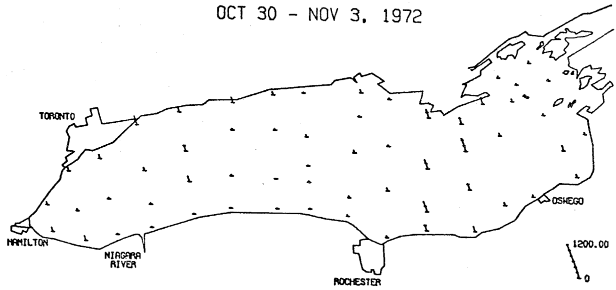


FIG. 56 continued.



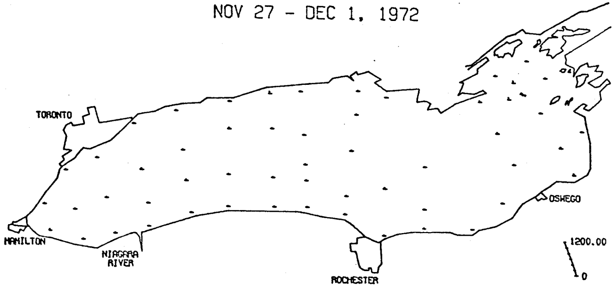
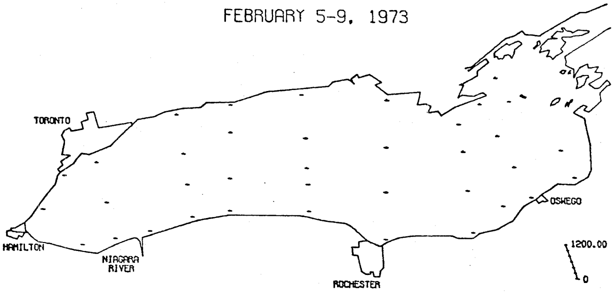


FIG. 56 continued.



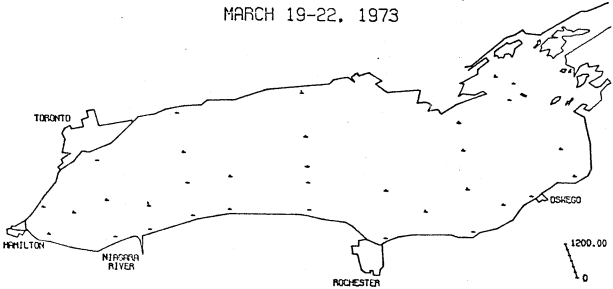


FIG. 56 continued.

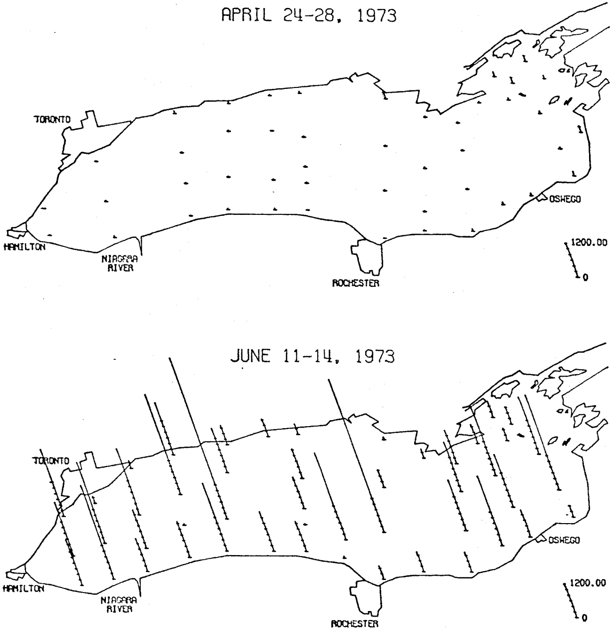


FIG. 56 continued.

than 10 μm in largest dimension. Identification of preserved specimens of these organisms is exceedingly difficult, and the species occurring in the Great Lakes phytoplankton have been, historically, very poorly treated. Although reliable published records are lacking, our observations indicate that organisms in this group are relatively much more important in the Lake Ontario system than they are in the upper Great Lakes. The most abundant organisms in this class occurring in our collections were *Chlamydomonas* spp. (probably including zoospores of other chlorophycean species), *Chrysochromulina parva* Lackey, *Pedinomonas* spp., and *Rhodomonas* spp., although less abundant populations of other chrysophycean flagellates were present at many stations. As Munawar and Nauwerck (1971) noted, *Rhodomonas* was present during all seasons and its abundance seemed to follow the general trends of total phytoplankton abundance. In our collections *Chrysochromulina* was most abundant in June and July, with a minor peak in populations in the fall. *Chlamydomonas* spp. appeared to have a similar seasonal succession although they tended to become abundant somewhat later and abundance peaks were similar to other chlorophycean species. Although Munawar and Nauwerck indicated that *Pedinomonas* was primarily a summer form, in our collections it became abundant at nearshore stations in the early spring and reached peak abundance at open-lake stations in June. This is not surprising, in that Huber-Pestalozzi (1961) indicates that *P. minutissima* Skuja, which is probably the main species involved, is a cold stenotherm.

Microflagellates were abundant at the shallower stations during the May 1971 cruise, and high population densities were noted at stations in many parts of the lake during June. In this month, however, there was a consistent pattern of low population densities at stations nearest shore in the western part of the lake between Niagara and West Point and at offshore stations in the southern half of the lake. Appreciable populations of microflagellates were still present in July, but peak abundances were down considerably from June values. At this time highest population density occurred at station 14 near Niagara. Population levels of microflagellates were further reduced in August and only relatively low population densities were found throughout the lake. Average abundance of this group increased somewhat in October samples, but was low in November and remained low during February and March 1973 cruises. A general increase in abundance of the group was noted in the April samples, and notably increased densities occurred at several stations in the eastern part of the lake. An extreme bloom of these organisms apparently occurred at the time the June 1973 samples were taken, and abundance in excess of 5000 cells/ml were noted at several offshore stations. Highest abundances at this time substantially exceeded any found during 1972.

Vertical Distribution of Phytoplankton at Master Stations

In the following sections, data are given on the vertical trends in total phytoplankton abundance and the abundance of major groups at different

seasons. Data are derived from standard sampling depths at the master stations.

In general, these data are relatively well correlated with trends in chlorophyll concentration (Table 6), and particle counts (Table 7) both for total phytoplankton and for particular groups during their maximum growth phase, and relatively poorly correlated during periods of decline.

The vertical distribution of total phytoplankton cell counts at master stations is shown in Figure 57. Open lake stations sampled during May had relatively low and uniform counts at all depths, with a slight increase in the 20 m sample from station 24. Cell densities were considerably higher at station 96, but no stratification of cell densities was evident. In June, cell densities were still low and uniform at stations 45 and 75 and somewhat higher but still uniform with depth at station 10. At station 24, however, very large values were found in samples from the top 15 m, and samples from the lower depths had higher counts than all stations except station 96. In July, stations 24, 45, and 75 in the central part of the lake had relatively high counts in the epilimnion, with peak values occurring at 5, 10, and 15 m. Station 10, in the western end of the lake, and station 96, in the eastern end both had lower and more vertically uniform phytoplankton counts. In August, cell counts were considerably reduced at the open-lake stations, with peak values occurring in the top 10 m. At station 96, on the other hand, phytoplankton density increased from levels noted the previous month, with especially large values present in the 5 and 10 m samples. By October less pronounced stratification was evident and cell counts were relatively low and irregular, even at station 96. Abundance continued to decrease at the main-lake stations sampled during November, but remained near levels noted the previous month at station 96. Phytoplankton densities were low and uniform at all stations sampled during February, and only slight increases were noted at the main lake stations during March although a large increase was found at station 96. Approximately the same situation was present in April, although slight increases were noted at stations 10 and 24 and values continued to increase at station 96. By June 1973 values had increased greatly at all stations sampled, and phytoplankton densities were strongly stratified at all stations. Peak values occurred at 5 or 10 m depths and the anomolous 30 m peak noted in the cholorophyll results were evident from the counts.

The vertical trends in abundance of the major phytoplankton groups at the master stations sampled are shown in Figures 58-61.

The diatoms (Fig. 58) were the most consistently abundant at the master stations. In May, large populations were present at all depths sampled at station 96, with largest concentrations occurring in the near-bottom waters. Abundance was much lower at stations 24 and 75 and more evenly distributed with depth, although there was a noticeable concentration at the 20 m depth at station 24. In June, largest populations were

TABLE 6. Correlation between fluorometrically determined chlorophyll *a* values and cell counts in total and by category at master stations.

	Total cells ml	Macrofla-gellates	Blue-greens	Greens	Diatoms	R@.99
May	.8301	.9388	.6009	-.0464	.5409	.5256
June	.8875	.7924	.6715	.5350	.8508	.3801
July	.6703	.6309	.2409	-.2323	.4507	.3683
Aug.	.6285	.4297	.4858	.4960	.0568	.3646
Oct.	.6258	.6897	.3809	.2635	.5475	.3575
Nov.	.8169	.8301	.2253	.4017	.9218	.4128
Feb.	-.1367	-.2383	.0155	-.1895	-.1396	.4076
Mar.	.9584	.4338	.0027	.1425	.9660	.4487
April	.9129	.8506	.2920	-.0028	.9051	.3542
June	.8090	.7416	.2130	.0419	.7395	.3646

TABLE 7. Correlation of particle counts in channels measured with cell counts as determined by visual identification for master stations.

	Particle Count Channels						
	5-10μm	10-20μm	20-40μm	40-80μm	80-150μm	5-150μm	R@.99
MAY							
Total cells/ml	.7741	.7457	.6633	.4938	-.0031	.7594	.4705
Microflagellates	.7635	.8502	.8702	.7604	.0996	.8345	
Blue-green	.2499	.2475	.2267	.1266	-.1237	.2544	
Green	-.2156	-.1874	-.2019	-.1466	.2030	-.2118	
Diatoms	.6764	.6300	.5086	.3196	-.0842	.6609	
JUNE							
Total cells/ml	.7285	.7229	.2886	.3634	.5785	.7396	.3646
Microflagellates	.7025	.6529	.2273	.3830	.7020	.6963	
Blue-green	.5585	.4799	.2137	.2934	.6119	.5447	
Green	.3683	.3099	.0915	.1618	.3960	.3531	
Diatoms	.6711	.7183	.3159	.3268	.4022	.7006	

TABLE 7 continued.

	Particle Count Channels						
	5-10μm	10-20μm	20-40μm	40-80μm	80-150μm	5-150μm	R@.99
JULY							
Total cells/ml	.5348	.7348	.6425	.2366	.0492	.5976	.3646
Microflagellates	.5945	.7318	.7234	.4296	.2380	.6461	
Blue-green	.2602	.2267	.0668	.0305	-.0129	.2559	
Green	-.3168	-.2469	-.3000	-.3611	-.3174	-.3110	
Diatoms	.2670	.4458	.3298	-.0150	-.1180	.3157	
AUGUST							
Total cells/ml	.3829	.5539	.5877	.4515	.3566	.4315	.3646
Microflagellates	.5088	.5852	.2088	.2040	.5857	.5274	
Blue-green	.1658	.2695	.5726	.4208	.0753	.2061	
Green	.2100	.3640	.5490	.3935	.1242	.2594	
Diatoms	-.1235	-.0850	.0993	.0639	-.0616	-.1108	
OCTOBER							
Total cells/ml	.2728	.3629	.3697	.2857	.2720	.2987	.3683
Microflagellates	.2417	.3114	.3122	.2080	.1270	.2620	
Blue-green	.2185	.2550	.2432	.1726	.0979	.2302	
Green	-.0448	.0900	.1451	.2111	.4817	-.0117	
Diatoms	.2871	.3794	.3946	.3099	.3850	.3141	
NOVEMBER							
Total cells/ml	.7016	.7864	.7663	.7321	.3292	.7447	.4128
Microflagellates	.6825	.7546	.7259	.6820	.3010	.7195	
Blue-green	.1852	.2525	.2580	.2633	.0963	.2151	
Green	.2214	.3229	.3366	.3312	.2367	.2660	
Diatoms	.8451	.8974	.8618	.8155	.3709	.8765	

FEBRUARY no significant correlation

TABLE 7 continued.

	Particle Count Channels						
	5-10μm	10-20μm	20-40μm	40-80μm	80-150μm	5-150μm	R@.99
MARCH							
Total cells/ml	.7902	.9153	.9235	.8723	.1203	.8594	.3978
Microflagellates	.4044	.3124	.2550	.3094	.0285	.3851	
Blue-green	.1572	.0675	.0561	.1074	-.0336	.1324	
Green	.1607	.1080	.0908	.0205	-.1611	.1447	
Diatoms	.7859	.9252	.9370	.8821	.1308	.8599	
APRIL							
Total cells/ml	.3377	.6315	.7988	.3606	.0484	.5265	.3542
Microflagellates	.1600	.5214	.7264	.3448	.0810	.3669	
Blue-green	.2735	.2678	.2139	.0735	-.0007	.2908	
Green	-.2955	-.0203	.0195	.1111	.1912	-.1937	
Diatoms	.3604	.6319	.7951	.3513	.0342	.5407	
JUNE							
Total cells/ml	.5649	.7377	.7200	.7507	.6478	.6476	.3683
Microflagellates	.4940	.7240	.6280	.7013	.6854	.5836	
Blue-green	.3517	.1963	.1364	.2331	.2214	.3336	
Green	.2305	-.0226	-.0613	-.0383	.0179	.1795	
Diatoms	.2918	.6295	.8430	.7275	.3852	.4073	

found at station 24, which had an extreme peak at the 15 m sample depth. Relatively high numbers were present at the surface of station 10, but declined below. Stations 45 and 75 had lower and more vertically uniform abundances of diatoms, although there was a concentration in the near-bottom sample from station 75. Populations at station 96 were reduced from the levels noted the previous month, but the trend towards highest concentrations in the near-bottom waters was still evident. In July, abundance of diatoms was notably reduced at all depths sampled at station

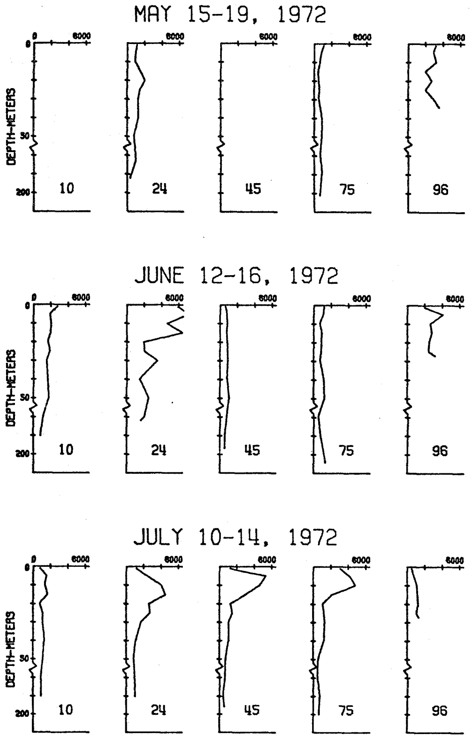


FIG. 57. Vertical distribution of total phytoplankton cell counts at master stations.

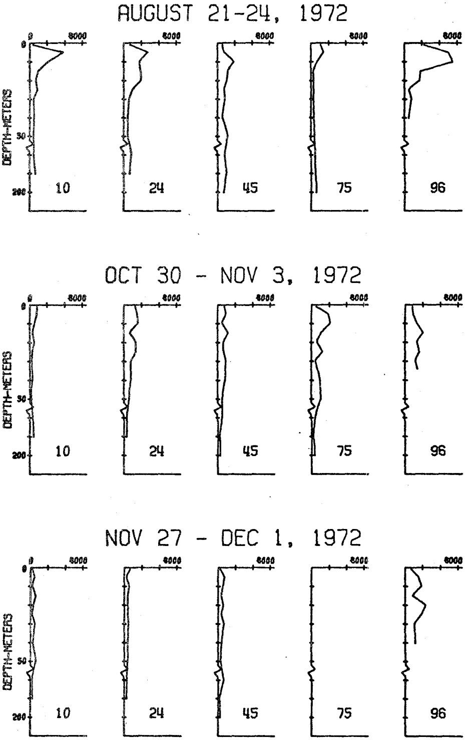


FIG. 57 continued.

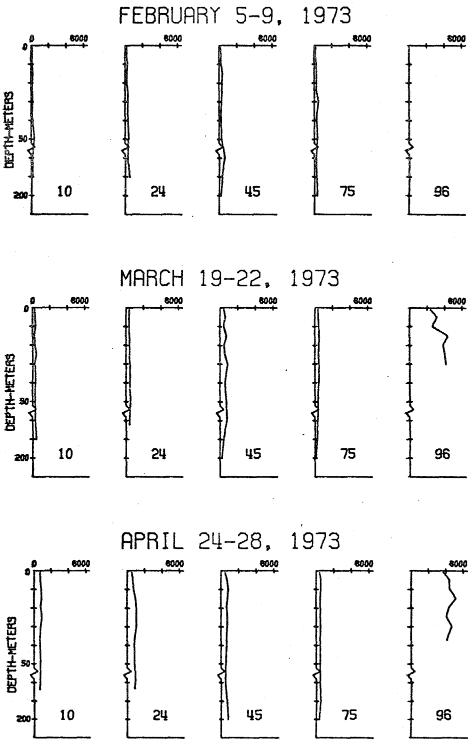


FIG. 57 continued.

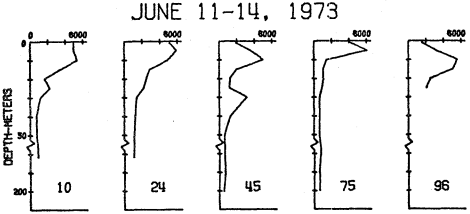


FIG. 57 continued.

96 and near the surface at station 10, but remained relatively high at lower depths. Station 24 had similarly low surface values, but a distinct peak at 15 m. Station 45 had a similar peak at 15 m, but the surface values were larger than at station 24. Station 75 had relatively high surface values also and highest concentrations at 5 m. Samples from August and October showed relatively low abundance of diatoms and relatively uniform abundance at all depths sampled, although there was a slight increase in abundance at all depths sampled at station 96 in October. In November there was a significant increase in abundance of this group at all depths sampled at station 96, but numbers remained low and vertically uniform at the other stations. In February, abundance of diatoms was low throughout the water column at all stations sampled. In March a slight increase was noted at most depths sampled at the main lake stations and very high numbers were present at station 96, with peak abundance occurring in the near-bottom samples. Abundance of diatoms continued to increase at the main lake stations sampled during the April cruise but remained relatively uniform throughout the water column. Abundance remained very high at all depths sampled at station 96. In June 1973 abundance of diatoms was considerably reduced at station 96, although distribution through the water column remained fairly uniform. Numbers increased at the offshore stations with peak abundance occurring at 10 or 15 m depth, except at station 75, where highest abundance was noted in the surface sample.

The abundance of green algae (Fig. 59) was more seasonal than that of the diatoms, and during most months they were a quantitatively less important part of the total phytoplankton assemblage. Samples from the May 1972 cruise showed relatively low numbers of green algae and uniform distribution throughout the water column. In June, numbers of green algae increased

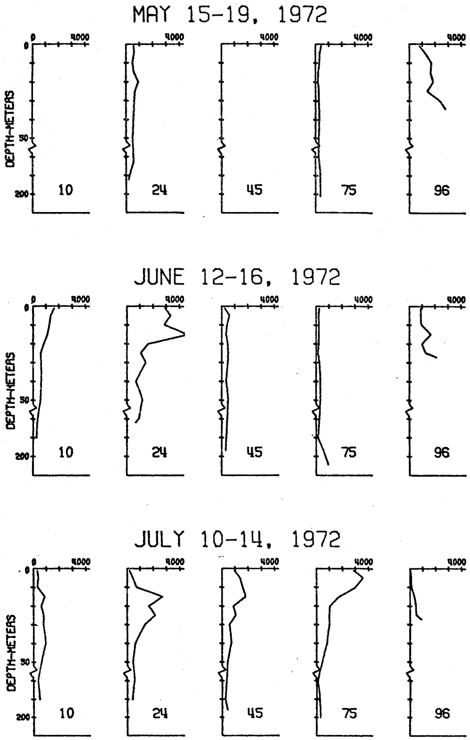


FIG. 58. Vertical distribution of diatoms at master stations.

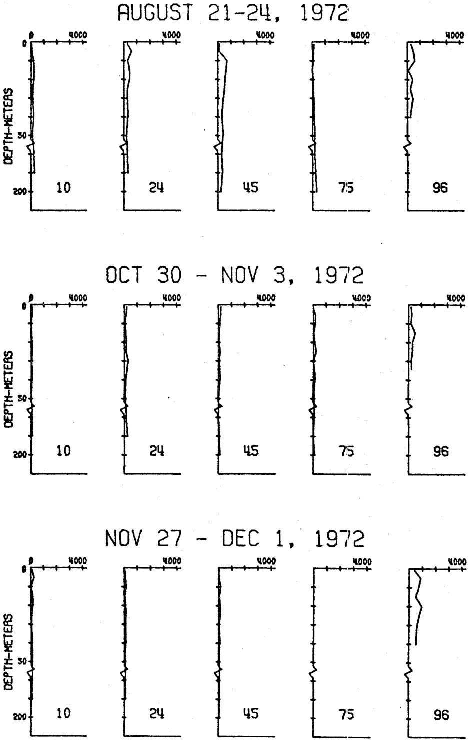


FIG. 58 continued.

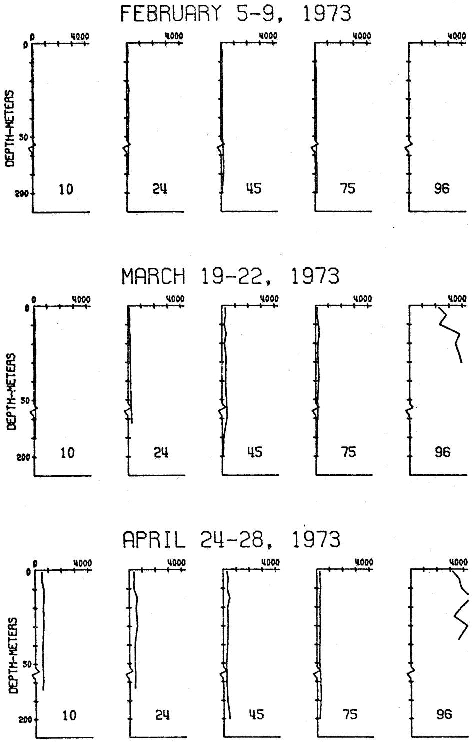


FIG. 58 continued.

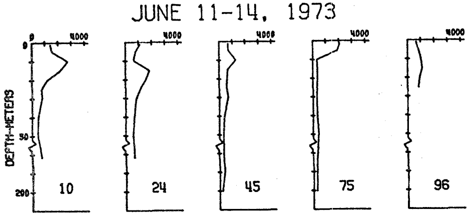


FIG. 58 continued.

significantly although vertical distribution of populations was very irregular. The major contributor during this month was *Scenedesmus bicellularis*. Samples from July showed reduced numbers and most significant concentrations occurred below 10 m depth. In August there was a large increase in the abundance of this group at stations 10, 24, and 96 and there appeared to be a significant concentration of populations at 10-20 m depth at these stations. Numbers were lower and less vertically stratified at stations 45 and 75. By October, abundance of this group had been reduced to very low levels except at station 96, and remained an insignificant part of the assemblage at all stations sampled during November 1972 and February and March 1973. In April a slight increase occurred at most stations and depths sampled. In June, very high abundance was found in the 10 and 15 m samples from station 96. At the other stations sampled numbers remained relatively low, but subsurface peaks were evident.

Compared to the other groups, the blue-green algae (Fig. 60) constituted a relatively small part of the phytoplankton assemblage in most samples from the master stations. Small surface concentrations were noted at station 96 in May and at stations 10, 24, and 96 in June. In July, highest concentrations of these organisms occurred below 10 m at stations 24 and 96. The highest concentrations noted during this study were found in samples from the upper 10 m at station 96 during the August cruise. By October relatively low levels of blue-green algae were found at all stations and depths sampled. Although numbers were further reduced, populations were noted at most stations and depths during November. In February, March and April 1973 this group was mostly represented by low-level populations of *Oscillatoria* spp. occurring at depth. During the June 1973 cruise some increase in the abundance of this group was noted at station 96 and in the surface samples from station 24.

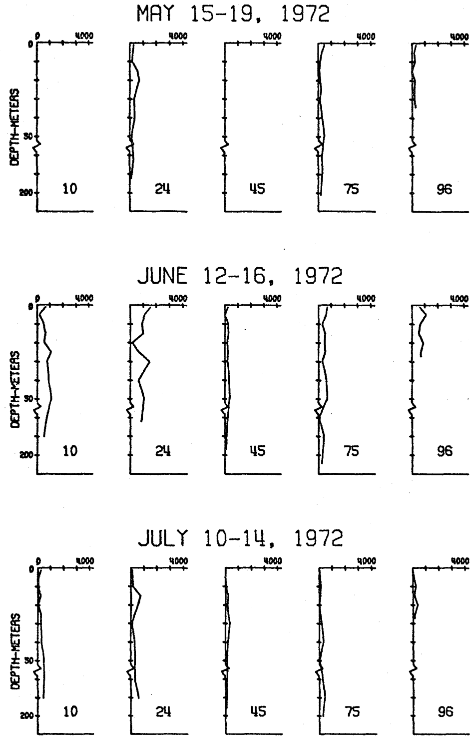
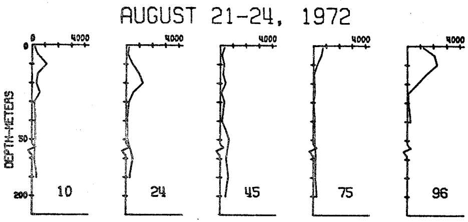
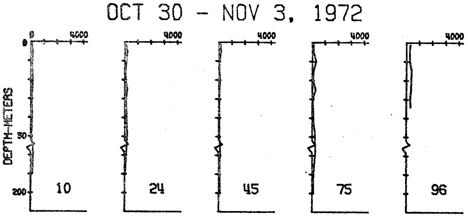


FIG. 59. Vertical distribution of green algae at master stations.





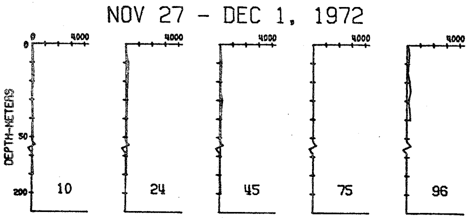


FIG. 59 continued.

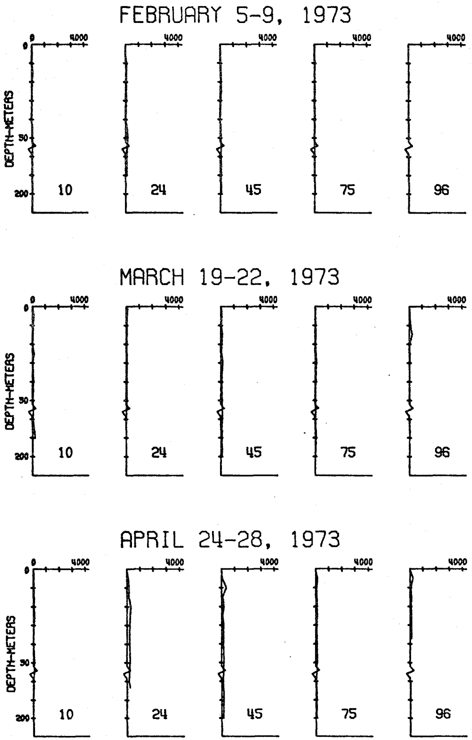


FIG. 59 continued.

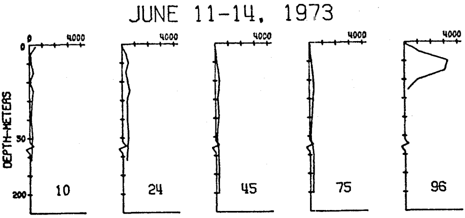


FIG. 59 continued.

As might be expected, the vertical distribution of microflagellates (Fig. 61) was somewhat more restricted, especially during the summer months, than the other major groups of phytoplankton. In May relatively high numbers of organisms in this group were noted at station 96, but other stations had significantly lesser numbers. By June 1972 abundance was present in 5 m samples from stations 24 and 96 but numbers remained relatively low at other stations and depths sampled. During the July cruise high abundance was noted at the 10 m depth of station 24 and at 5 and 10 m samples from station 45. Somewhat smaller concentrations were found at 5 and 10 m depths at the other stations. In August highest concentrations occurred in the 5 m samples from stations 10 and 24. Somewhat smaller numbers were noted at 10 m at station 45 and 5 m from stations 75 and 96. By October, numbers of this group had been reduced and abundance was more uniformly distributed throughout the water column. Numbers were vertically uniform and relatively low at all stations sampled during November 1972, except station 96 where numbers were somewhat larger. Abundance of this group was low at all stations and depths sampled during February 1973, and only slight increases were noted in March samples. In April there was some increase at station 96, but numbers remained low at other stations sampled. During June 1973 relatively high numbers of microflagellates were noted in all samples from the top 20 m at all main lake stations, but considerably lower numbers were present at station 96. A notable secondary peak in abundance occurred in the 30 m sample from station 45.

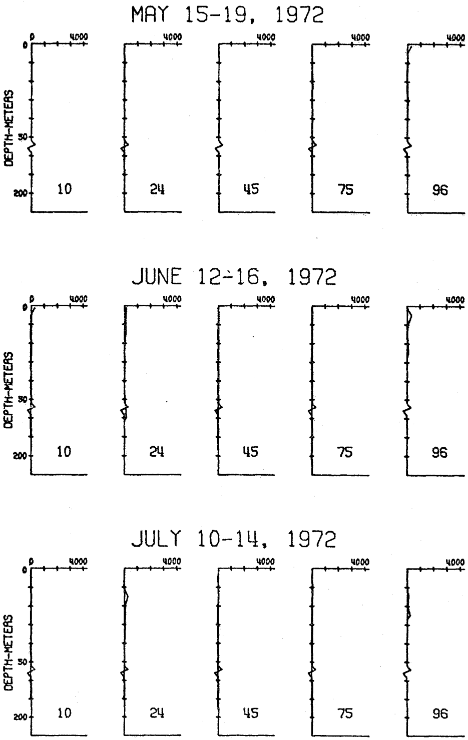


FIG. 60. Vertical distribution of blue-green algae at master stations.

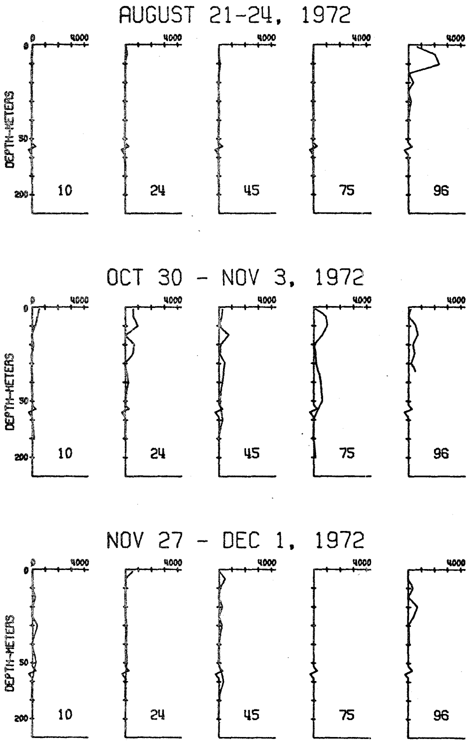


FIG. 60 continued.

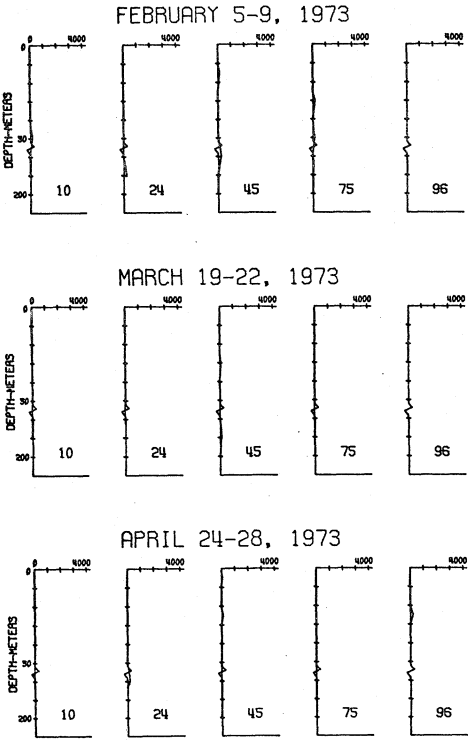


FIG. 60 continued.

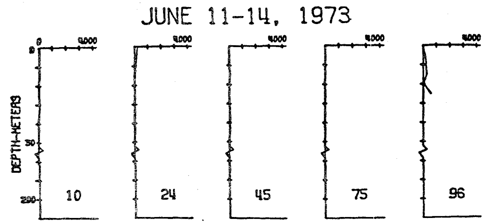


FIG. 60 continued.

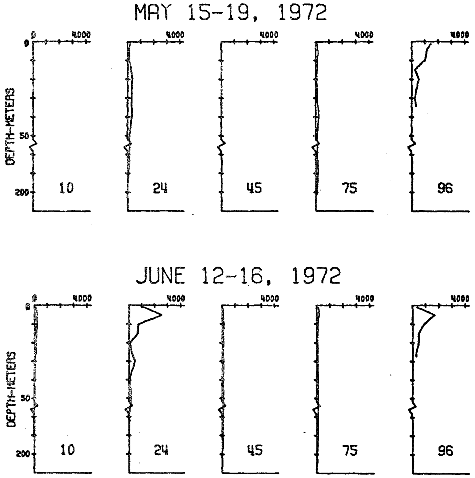


FIG. 61. Vertical distribution of microflagellates at master stations.

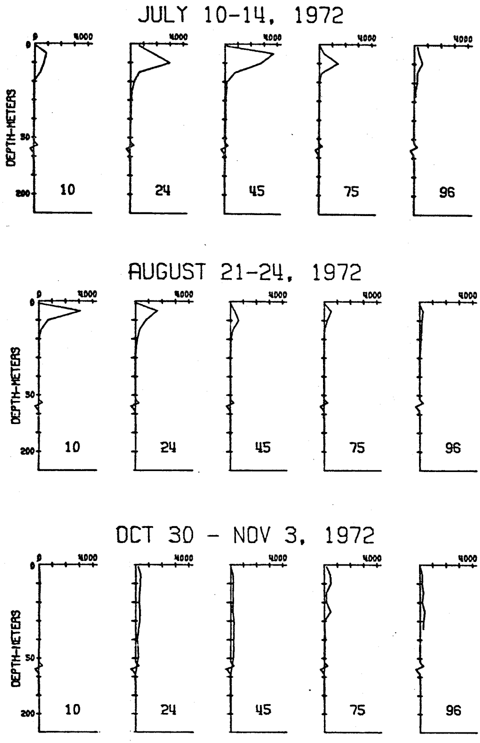


FIG. 61 continued.

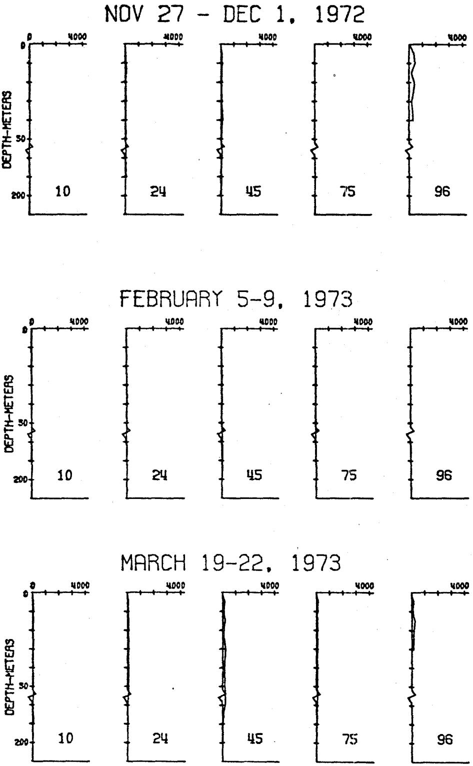


FIG. 61 continued.

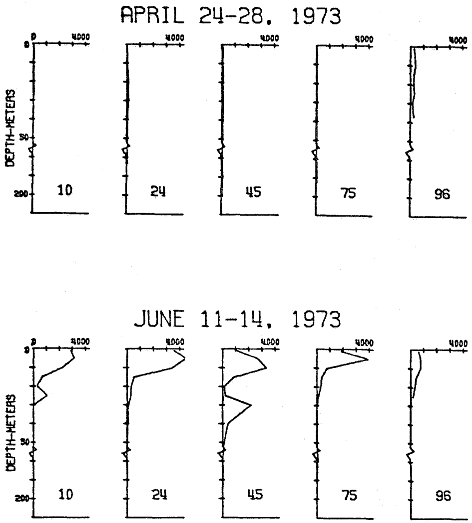


FIG. 61 continued.

DISCUSSION

Because of its geographical position, Lake Ontario was the first of the Great Lakes to receive substantial impact from the activities of western man. It has received, and continues to receive, loadings of materials originally introduced to other parts of the system. This is, of course, particularly true of conservative ions although there is undoubtedly a considerable pass-through of more physiologically active materials. As a result we have only a very sketchy knowledge of what the original quasi-equilibrium state of the system might have been. In the case of the primary producer communities, particularly the phytoplankton, there has been no attempt to determine the previous composition and characteristics of the flora as there has been in Lake Erie (Hohn 1969) and Lake Michigan (Stoermer and Yang 1969). In the case of Lake Ontario, recovery of samples taken before significant environmental perturbation had already occurred may not be possible, since the available evidence suggests that large-scale and so far unreversed changes took place very early in this system.

As is generally the case in the Great Lakes, the most extensive and dramatic evidence of such change comes from the fisheries records (Baldwin and Saalfeld 1962; Smith 1972; Parsons 1973). These indicate certain of the original top predator fish populations in Lake Ontario collapsed several decades before similar occurrences in the upper lakes. It would appear, in fact, that the high populations of Atlantic salmon which were unique to Lake Ontario had essentially been exterminated by the turn of the century. Although destruction of the indigenous populations of desirable fish in the lake undoubtedly resulted from a combination of causes, some of which are only indirectly related to changes in primary producer communities, the fact that subsequent attempts to establish artificially managed populations of the same species have met with universal failure indicates that fundamental changes occurred in the Lake Ontario ecosystem as early as the beginning of the present century.

Since, as Davis (1966) has noted, early studies of primary producer communities, including phytoplankton, from Lake Ontario are scarce, even compared to the other Great Lakes, the true nature and magnitude of change in the open water phytoplankton community can only be inferred at the present time from comparison of slightly better known sequences in the upper lakes. The majority of historic studies which are available (Burkholder and Tressler 1932; Tressler and Austin 1940; Tucker 1948; Tressler et al. 1953) dealt primarily or exclusively with bays or other areas which cannot be considered representative of conditions in the open lake. Both these studies, and more recent studies which treat with similar areas or the nearshore waters of Lake Ontario (McCombie 1967; Michalski 1968), however, have reported floras which could only be interpreted as representative of eutrophic waters. In light of reports of gross visual pollution of the nearshore waters of Lake Ontario (MacKay 1930) it would appear that such regions were substantially

disturbed before these studies took place.

Although direct evidence of floristic change is lacking, it is clear that the chemistry of the lake has been grossly altered since settlement (Beeton 1965, 1966, 1969) and that the standing crop of phytoplankton has been substantially increased (Schenk and Thompson 1965; Matheson and Anderson 1966; Davis 1966, 1969). Comparison of the trends in Lake Ontario with similar trends in the upper lakes leads to the conclusion that Lake Ontario must be the most highly modified of the Laurentian Great Lakes with the possible exception of Lake Erie. Beeton's data suggest that the degree of chemical change in Lake Erie and Lake Ontario are quantitatively similar, although the morphometric oligotrophy (Rawson 1961) of the latter body of water serves to somewhat modify biological effects.

Most recent studies have served to emphasize the fact that Lake Ontario is more severely eutrophied than commonly supposed. High levels of phytoplankton standing crop are present in all areas of the lake during most of the year (Chau et al. 1970; Nicholson 1970; Glooschenko et al. 1973) and primary production (Glooschenko et al. 1974) is, among the Great Lakes, second only to Lake Erie and exceeds it during certain seasons. Studies of the composition and seasonal succession of the phytoplankton community (Nalewajko 1966, 1967; Ogawa 1969; Reinwand 1969; Munawar and Nauwerck 1971) have revealed a flora dominated by species either tolerant of or requiring eutrophic conditions for growth and extreme successional patterns not characteristic of less modified regions of the Laurentian Great Lakes. Species belonging to the oligotrophic diatom association (Hutchinson 1967) which are a major component of the offshore flora in the upper lakes, are apparently largely absent from Lake Ontario.

Studies of the nutrient chemistry of the open waters of Lake Ontario indicate the presence of high levels of phosphorus and summer depletion of both silica and nitrate. It has been shown that phosphorus is the primary element controlling eutrophication in the Laurentian Great Lakes, and Schelske and Stoermer (1971, 1972) have postulated that increased loadings of this nutrient into the system, in addition to simply increasing gross productivity, substantially modify the composition and seasonal succession of phytoplankton flora indirectly. It appears that increased productivity due to increased phosphorus input leads first to depletion of silica and replacement of the perennial diatom flora during the summer stagnation by groups not requiring silica. Further increases in phosphorus loadings result in depletion of nitrogen sources in the epilimnion during stratification and confer competitive advantage on the nitrogen fixing species of blue-green algae. Both the chemical and biological results available to date suggest that Lake Ontario has already passed the first of these geochemical thresholds and is approaching the second. Indeed, as will be discussed later, it appears that nitrogen limitation is reflected in the composition of the late summer flora in certain areas of the lake at the present time.

The results of the present study largely confirm the trends and conditions which might be deduced from previous work. It is quite clear that, although

Lake Ontario is part of the same physical system, it is floristically in a different province from the upper lakes, above Lake St. Clair. The phytoplankton assemblages present are completely dominated by species which are apparently not indigenous to the upper lakes and which, even under present conditions, are abundant only in nearshore regions which have suffered considerable impact from man's activities. All of the diatom species which Hohn (1969) found becoming predominant in western Lake Erie as pollution increased are present in the offshore flora of Lake Ontario and many of them are the dominant elements of spring and winter assemblages. Species of green algae which are absent or present only in very low abundance in the offshore phytoplankton of the upper lakes completely dominate the summer and early fall flora.

Many of these species are capable of producing nuisance conditions of various sorts. Many of the small, colonial species of *Stephanodiscus*, such as *S. binderanus* and *S. tenuis*, have been implicated in taste and odor and filter clogging problems in local regions of Lake Michigan (Vaughn 1961). Some of the species of blue-green algae present such as *Aphanizomenon flos-aquae* and *Anacystis cyanea* are almost universally associated with nuisance summer blooms in temperate lakes. Indeed, considering the abundance and wide distribution of potentially nuisance producing phytoplankton species in Lake Ontario, it is somewhat surprising that the most commonly reported nuisance appears to be caused by overgrowths of benthic algae, particularly *Cladophora* spp.

One of the more surprising results of our study was the evident almost total absence of certain species which are universally among the dominant forms in the offshore waters of the upper lakes. We noted less than 50 occurrences of all of the species of the diatom genus *Cyclotella* which form the predominant association in the offshore waters of Lake Huron and Superior and are an important component of offshore assemblages in Lake Michigan. Other species usually considered "characteristic" of Great Lakes phytoplankton assemblages, such as *Rhizosolenia eriensis*, were very rarely noted in our samples. So far as the diatom component of the phytoplankton was concerned, there was a very striking similarity between the trends in abundance of taxa found in our samples from Lake Ontario, particularly the eastern part of the lake, and those reported by Hohn (1969) from western Lake Erie. The elements of the phytoplankton flora which are common to both Lake Ontario and the upper lakes are those apparently eurytopic species such as *Asterionella formosa, Fragilaria crotonensis, Ankistrodesmus falcatus, Botryococcus braunii, Cryptomonas erosa* etc. which enjoy almost universal distribution in both oligotrophic and eutrophic lakes. According to Hohn, the absolute abundance of some of the diatom species in this group did not change appreciably in Lake Erie between 1938 and 1965, which furnishes some notion of their tolerance. At the present time the species cited above, and several others, appear to be universally distributed in all areas of the Laurentian Great Lakes.

Another striking feature of the species composition of phytoplankton assemblages is the large number of species present whose general distribution includes freshwater habitats with considerable conservative ion

contamination and, in many instances, brackish water. In searching the general literature on phytoplankton species distribution one finds, with rather monotonous regularity, dominant and subdominant taxa in Lake Ontario described as having most abundant occurrences in brackish and saline inland waters. This serves to emphasize the fact that, while compositional changes which have occurred in the Great Lakes are generally attributed to eutrophication, in the strict sense, they really result from complex and interacting changes in the total chemical and physical milieu. While chlorides have apparently increased in Lake Ontario by over a factor of 3, it still can hardly be considered as brackish water. It may be, however, that the only species adapted to the physical conditions in the Great Lakes come primarily from saline water, and any considerable increase in conservative ion levels selectively favors increase in their abundance. It would appear that some general factor is operational, as the same distributional tendency is also found in some groups of invertebrates.

Another unusual characteristic of phytoplankton assemblages in Lake Ontario, compared to the upper lakes, is the extreme abundance of microflagellates, and particularly apparently heterotrophic species. The same observation has been emphasized by Munawar and Nauwerck (1971). While autotrophic flagellates are universally present and occasionally constitute an important part of the phytoplankton assemblages of the upper lakes, the extreme abundance of such species and particularly the relative importance is, in our experience, highly unusual. Although our work furnishes no direct support for such a hypothesis, it might be inferred that the waters of Lake Ontario have higher organic loadings than the upper Great Lakes. The same might be inferred from the apparently very high levels of "microzooplankton" observed in many of our samples. Although we made no quantitative estimates of abundance of these organisms, many of our samples contained astonishing numbers of ciliate protozoa and small rotifers. The high abundance of such forms was one of the strikingly gross qualitative differences between prepared samples from Lake Ontario and similar preparations made from samples from the upper lakes.

Our results also indicate that the seasonal succession of phytoplankton in Lake Ontario is much more pronounced than is characteristic for less disturbed areas of the Great Lakes. The thermal bar (Nalewajko 1966) appears to be an important factor in controlling the early spring changes in abundance and composition of the phytoplankton assemblage. Similar effects have been noted in the upper lakes, but appear to be largely confined to the nearshore waters, whereas the spring pulse following development of the thermal bar appears to proceed all the way across Lake Ontario. According to the available evidence (Gächter et al. 1974) it appears that this strong spring pulse results in selective depletion of nutrients essential to the species dominant in the spring flora, and sets the stage for the development of the thermal tolerant species characteristic of the summer and fall floras. In this regard it must be very strongly emphasized that our results probably represent an atypical case, so far as seasonal succession is concerned. As previously noted,

the spring of 1972 was unusually cold and wet. Chandler's early work on the western basin of Lake Erie (1940, 1942, 1944) has demonstrated the profound effects of local meteorological conditions on the abundance and seasonal succession of phytoplankton communities in disturbed areas of the Great Lakes. It is readily apparent that the successional trends noted during the spring of 1973 are more similar to those reported in previous investigations than those noted in the same period of 1972. It should also be noted that any results from monthly or bi-monthly sampling periods should be treated with caution in such a highly forced system. Due to the apparent high reproductive potential of many of the dominant forms in the Lake Ontario phytoplankton assemblage, significant peaks in abundance may have been either missed or considerably underemphasized. In the present case it is obvious that samples from September 1972 and May 1973 would have been very valuable in attempting to determine the true pattern of seasonal succession.

Although the extreme degree of instability apparent in the Lake Ontario system renders general conclusions somewhat difficult, certain patterns are apparent. There appears to be a general pattern of development of the spring bloom and subsequent successional changes to develop first at the eastern and western ends of the lake, then spread along the southern shore before becoming evident along the northern shore, and eventually the mid-lake region. Certain species appear to follow slightly different patterns which may be genuine or, in some instances, the result of the particular time frame examined by the sampling sequence, but the overall pattern appears to be reasonably consistent. In this regard Lake Ontario appears to differ significantly from its nearest analog, Lake Erie, where the quantitative and qualitative aspects of the phytoplankton flora appear to be strongly controlled by morphometric and nutrient gradients from the western to the eastern end of the lake. Successional patterns in Lake Ontario compare poorly with those noted in the upper lakes, where the only common feature appears to be the nearshore development of a spring bloom which is apparently controlled by the thermal bar. Recent results indicate that a strong shift towards summer dominance by green and blue-green algae, somewhat similar to that noted in Lake Ontario although quantities and dominant species involved are not comparable, is now a feature of the southern basin of Lake Michigan although this has not been noted in previous studies.

Our results also indicate that certain regions of the lake are more highly eutrophied than others. In general, the shallow region from the vicinity of Nine Mile Point around the eastern and northeastern shore to Point Petre was the region in which bloom conditions were first noted and where average phytoplankton densities were largest throughout a significant portion of the year. It was also in this region that the highest and most persistent populations of extremely pollution tolerant forms such as *Aphanizomenon flos-aquae* and *Cosconodiscus subsalsa* were noted. It would appear that at least some of these populations may first develop in the numerous shallow bays in this region and subsequently spread into the open waters of Lake Ontario. Although our samples furnish no direct support for this supposition, similar occurrences were

noted at stations in the vicinity of Presqu'ile Bay where there are extensive shallows connected to the Bay of Quinte by the Murray Canal. This sort of "morphometric control" of phytoplankton composition, which Gächter et al. (1974) propose as an important mechansim in eutrophied regions of the Great Lakes, is probably also operational in our results from other regions of the lake. It might be suspected that strong gradients would be present in regions of high population concentration and consequent material loadings to the lake, such as areas near Toronto, Hamilton, the Niagara outlet, Rochester, and Oswego. Effects of these regions on phytoplankton abundance and assemblage composition are indeed apparent in our results in a large number of cases but the patterns are less consistent than those visible in the eastern region of the lake. In this respect it should be pointed out that while we have rather loosely referred to stations nearest shore as nearshore samples, none of our stations were actually in the highly impacted nearshore zone as commonly defined in recent work on the Great Lakes. Although a general pattern of the impact of these regions on phytoplankton dynamics in Lake Ontario can be inferred from our work, critical evaluation of such impacts will depend on the results of other IFYGL projects which have concentrated on nearshore boundary regions.

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